

1-1-2014

## A Climatology of Prescribed Burn Day Criteria for the Southeastern US

Brandon Harold Sylvester

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A climatology of prescribed burn day criteria for the Southeastern US

By

Brandon Harold Sylvester

A Thesis  
Submitted to the Faculty of  
Mississippi State University  
in Partial Fulfillment of the Requirements  
for the Degree of Master of Science  
in Geospatial Sciences  
in the Department of Geosciences

Mississippi State, Mississippi

December 2014

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2014

A climatology of prescribed burn day criteria for the Southeastern US

By

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Pages in Study: 69

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The United States has arbitrary weather criteria for a prescribed burn day to happen. This arbitrary criteria gives prescribed-burn managers a limited amount of days they can burn. To solve this, I established a 30-year climatology based on daily mixing height (m). I then calculated burn-day thresholds based on different mixing heights. I found seasonal and spatial patterns of the amount of days that are prescribed burns. Southeastern United States was my study area. A small decrease in threshold values will lead to large increases in prescribed burn days. Digital maps were created to show the spatial variability of prescribed burn days and the effects of lowering thresholds for prescribed burn days. This research will aid policy makers in lessening the criteria for burn days.

Key words: climatology, prescribed burns, gis, mixing height

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## CHAPTER I

### LITERATURE REVIEW

#### 1.1 Topic

For my thesis I evaluated mixing heights that affect the average annual prescribed burn days. I first established climatology of mixing heights. I first looked at how many prescribed burn days there would be if the mixing height was  $\geq 1800$  meters (m). I then decreased the threshold in 200 m increments. I have found sensitivity of threshold values to the annual number of days that are suitable for prescribed burns. The selection of these thresholds were based on previous literature.

#### 1.2 Introduction

Prescribed burning is “fire applied to fuels under certain weather criteria that accomplish certain goals” (Lunsford et al. 1989). Haines et al. (2001) found that in the Southern United States there are several barriers associated with prescribed burning. Some of these barriers include air quality and smoke regulations, shortage of personnel, risk of liability, narrow time frame to prescribe a burn, lack of funding, residential development, and public opinion. Prescribed burning has been around for centuries, and was started by Native Americans (Ryan et. al 2013). European settlers later adapted these techniques to control the understory growth of forests. By the end of the 19<sup>th</sup> century the logging industry deforested millions of hectares. Prescribed burning was not used as an

official tool until the 1950s in the Southern United States. During this time, prescribed burning was established for the Coastal Plain and lower Piedmont pine habitats. Prescribed burning would then be expanded into the mountains during the 1980s (Goodrick et al. 2012). Vegetation in the Southern United States is highly adapted to fire. Some vegetation such as thick-barked trees, light or winged seeds, and buried buds require fire in order to regenerate. According to Goodrick et al. (2012), over 6.4 million acres were burned by prescribed burning in the southern United States in 2011. Prescribed burning is less expensive and more environmentally friendly than chemical or mechanical treatments.

### **1.3 Cost of Prescribed Burns**

Cost is one of the primary factors in the decision to apply prescribed fire. Hesseln (2000) discusses prescribed burning from an economic viewpoint. Primary concerns of policy makers are public safety, risk of escape, smoke dispersion, air quality, and fiscal responsibility. Some factors that are associated with cost are burn preparation, ignition type, number of acres burned, and air quality (Hesseln 2000). Wood (1988) found costs to range from \$1.13 to \$13.62 per hectare depending on the amount of hours worked, crew size, fireline preparation, and equipment.

### **1.4 Effectiveness of Prescribed Burns**

Along with cost, effectiveness is important to decision making for prescribed burns. Anderson and Hales (1986) used a fire behavior prediction system to predict and compare fuel treatment effects on potential fire hazards. They found that fire intensity for a particular hazard dropped by 80 to 98% after treatment. Similar findings occurred for

European pine stands (Rego, 1991, Vega, 1994, Botelho et al., 1999). Effectiveness varies based on location and vegetation. Outcalt and Wade (2000) found that in Florida, wildfires burned across 10,000 hectares of the Osceola National Forest. This occurred even though the region had prescribed burns routinely. On the other hand, chaparral that was burned regularly in California was able to contain 11 wildfires in red flag conditions. Martin et al. (1988) did a study that compared wildfire activity between treated and non-treated areas. He found that 91.5% of the area burned by wildfires larger than 40 hectares occurred when prescribed burning was not used in the past three years. In this scenario, an estimated 4500 hectares of forest were saved by prescribed burning (Martin et al. 1988).

### **1.5 Pros of Prescribed Burns**

When deciding to ignite prescribed burns, managers and policy makers evaluate the benefits of prescribed fires. Some benefits include reducing hazardous fuels, preparing sites for seeding and planting, and improving wildlife habitat. Goodrick et al. (2012) suggest that fuels will be above pre-burn levels after 3 to 4 years following prescribed burning. Prescribed burning can prevent competing vegetation from taking over before the seeds are established. Fire also recycles nutrients, making the area more suitable for vegetation. Without prescribed burning vegetation that was once abundant over an area can now become endangered.

### **1.6 Cons of Prescribed Burns**

Goodrick et al. (2012) discusses how prescribed burning affects water and air quality. The principal concerns for water are runoff, increase in sediment, nitrate, and

heavy metal content. If there is not enough smoke dispersion then it could create health problems for humans. It also could impact visibility. Regional air quality would be affected only if many acres were burned on the same day. Since smoke can be produced fast in a given area, there is a higher chance of prescribed fires affecting the local scale. The amount of particulates put into the air from prescribed burns depends on the amount of fuel, moisture content, and how fast the fire is spreading. Rate of smoke dispersion is based on atmospheric stability and wind speed.

### **1.7 Weather elements involved in prescribed burn days**

Weather, topography, and fuels determine fire behavior. The greatest requirement to prepare a prescribed burn prescription is weather conditions. Some weather conditions that must be included are surface and transport wind speeds, relative humidity, and mixing heights (Lunsford et.al 1989, Goodrick & Waldrop 2012).

Surface winds carry away moisture from the air and accelerates fuel drying (Runyen 2007). Wind also increases oxygen levels, which increases combustion. Wind can also contribute to spotting. Spotting is when fire spreads the embers from one fuel to a new fuel. Winds from 20 to 70 mph ( $8.94$  to  $31.29\text{ ms}^{-1}$ ) have been responsible for the spread of large wildfires. An increase in winds from 1 to 10 mph ( $0.45$  to  $4.5\text{ ms}^{-1}$ ) would increase some fuels' rate of spread five times (Green 1981). Winds carry heated air to the fuel on the lee side and raise the fuel temperature, thus vaporizing moisture. The direction of fire spread is determined by the wind direction. For a prescribed burn, the best range of 2-m wind speed is  $2.24$  to  $6.71\text{ ms}^{-1}$  (5–15 mph) (Runyen 2007). Wind speeds below  $2.24\text{ ms}^{-1}$  (5 mph) will create poor burning conditions and the spread of fire will become unpredictable. Wind speeds above  $6.71\text{ ms}^{-1}$  (15 mph) will reduce fuel consumption and



increase risk of spotting. Wind also needs to be in a steady direction. Wind speed is a weather constraint depending on the vegetation-climate types. Burning is best in Oklahoma for short grass and mixed prairies during March and April. High wind during this time of year is commonly a reason for disallowing prescribed burns (Roberts et al. 2006).

Prescribed burns are ineffective when relative humidity (RH) is too high. On the other end, burns can be uncontrollable if RH is too low (Runyen 2007). Low RH can make fuels dry causing spot fires. Wier (2004) looked at the probability of spot fires during a prescribed burn. He found that 21 prescribed burns in Oklahoma caused spot fires. Of these, 17 were administered when RH was 20 to 30% (Wier 2004). He found the optimal RH range for a successful burn is 25–60%. Goodrick et al. (2012) suggest a very similar range of 30–55%. These two ranges are based on the southern region of the United States. Cramer (1957) found that in the Northwest, the RH range change drastically from location to location. The optimal RH range can also change based on the time of year. During the winter RH from 20 to 40% is sufficient for prescribed burns. During the summer, RH from 35 to 60% (Brender and Copper 1968) is sufficient for prescribed burns. Seasonal changes are apparent in RH. Western fire-weather seasons begin after a moist spring and continue into the early fall. Temperature is the greatest in fire season (i.e., lowest RH) during the day and dramatically decreases during the night (highest RH). As the season continues, the soil and vegetation dry out, daytime RH declines and the diurnal range diminishes.

The last weather element that influences prescribed burns is atmospheric stability. Stability can be divided into mixing heights and transport wind (Goodrick et al. 2012).

Mixing heights are simply heights at which a parcel of air or smoke will rise, mix, or disperse. The optimal range of mixing heights for prescribed burns to be effective is ~500–1800 m (1700–6000 feet; Runyen 2007). Holzworth (1967) found seasonality of mixing heights. Mixing heights were the deepest from April to August and the shallowest from December to January. This is because mixing heights are deepest with high surface temperatures. The high surface temperatures create warm, buoyant parcels of air. If the parcel of air is warmer than the environment around it then the parcel will continue to rise. Thus, a warmer surface temperature will create a greater mixing height. Mixing heights cannot be used when burning in mountainous terrain because they are difficult to predict with accuracy. This is due to having multiple inversions happen at multiple times of the day in mountainous terrain. Mountainous terrain increases the likelihood of plume collapse. Plume collapse is when smoke is transported over higher terrain that is then returned to the boundary layer and mixed to the ground (Achtemeier and Liu 2009).

Transport winds are the average wind speed and direction from the surface to the mixing height. Transport winds are usually used in smoke management calculations. Surface winds are usually measured near 2 m above ground. When surface wind speed and direction are stable, prescribed fires move in a predictable manner (Goodrick et al. 2012). The speed and direction of wind controls how fast and far the fire will spread. During the dormant season, burns are most effective when utilizing west to northwest winds behind a cold front. These postfrontal winds are strong and unidirectional which make them great for controlling prescribed burns. Runyen (2007) suggests the preferred range for transport wind speeds are 4–9 ms<sup>-1</sup> (9–20 mph). Holzworth (1967) found the average transport wind in the United States to be 4.5–8 ms<sup>-1</sup> during the afternoon. Faster

transport winds occur during the cool season (November through April) and slower transport winds occur during the warm season (June through October). Runyen (2007) also found some problems with transport winds and mixing heights. If mixing heights and transport winds are both low, then smoke may not disperse from the surface. If there are strong winds with low mixing heights, smoke may spread at very low altitudes.

## CHAPTER II

### METHODS

My thesis consisted of three parts. The first part was establishing burn day climatology. The second part of the thesis was analyzing statistics on weather variables. The final part of the thesis was analyzing the sensitivity of threshold values to the annual number of days that were suitable for prescribed burns. My study area was Mississippi, Florida, and South Carolina located in the Southeast United States. These states based on the statistics from the National Interagency Fire Center gave a good sample of prescribed burn days in the Southeast. Mississippi represents states that have fewer burns than most of the nation. Florida represents states that have moderate numbers of burns compared to the nation. South Carolina represents states that have high number of burns than most of the nation. The burn day climatology focused on one weather element which was mixing height. Mixing height was used to determine if the smoke from the prescribed burn would disperse easily. If low mixing heights occur the smoke will not disperse and will stay near the ground. This can cause visibility problems. We assume that an unstable environment is occurring when using mixing heights. The best approximation for an unstable environment was established by Arya (1981; Equation 2.1).

$$h_1 = 0.142(U_0/f) \quad (2.1)$$

$U_0$  = sfc roughness coefficient \* wind speed

where  $U^*$  is the frictional velocity. To estimate the frictional velocity we must know the surface roughness coefficient. I used EPA's approximation for surface roughness coefficient.

The only data source needed was from the Climate Forecast System Reanalysis (CFSR). This dataset contained u and v components of wind. I established thresholds to determine prescribed burn days using R and Python programming (Appendix A and B). I looked at different mixing heights of the climatology and saw how many prescribed burn days would be allowed if the mixing heights were reached. I then decreased the mixing heights by 200 m increments. The heights were  $\geq 1800$  m,  $\geq 1600$  m,  $\geq 1400$  m,  $\geq 1200$  m, and  $\geq 1000$  m. These results were then displayed using GIS to see how prescribed burn days changed from state to state and criteria to criteria

## CHAPTER III

### MISSISSIPPI RESULTS

#### 3.1 Overall

Prescribed burn days exhibited a contrast between northern, central and southern Mississippi. Annual prescribed burn days ranged from 0 to 185 days for the 30 year period (Figure 3.1). Looking at  $\geq 1800$  m mixing heights, average annual prescribed burn days ranged from 0 to 52 (Figure 3.2). Using  $\geq 1600$  m mixing heights, average annual prescribed burn days ranged from 1 to 69 (Figure 3.3). Looking at  $\geq 1400$  m mixing heights, average annual prescribed burn days ranged from 3 to 94 (Figure 3.4). Using  $\geq 1200$  m mixing heights, average annual prescribed burn days ranged from 7 to 123 (Figure 3.5). Looking at  $\geq 1000$  m mixing heights, average annual prescribed burn days ranged from 15 to 159 (Figure 3.6). Throughout all of these mixing heights, northern and southern Mississippi experienced relatively high number of days. However, central Mississippi experienced relatively low number of days.

#### 3.2 Seasonality

Each area of Mississippi experienced a difference in the amount of prescribed burn days based on time of year. For northern Mississippi the highest amount of prescribed burn days occurred from December through April. Prescribed burn days declined during from May through August in northern Mississippi (Figures 3.7–3.11).

For most of the mixing heights central Mississippi had two distinctive seasons (Figures 3.12–3.16). The first season which occurred from December through April had relatively high prescribed burn days. The second season which occurred from May through November had relatively low prescribed burn days. While looking for mixing heights  $\geq 1200$  m, southern Mississippi had the highest amount of prescribed burn days occurred from November through March (Figures 3.17–3.21). Prescribed burn days declined during from April through August in southern Mississippi using mixing heights  $\geq 1200$  m. Prescribed burn days in southern Mississippi were similar throughout the year when using mixing heights  $\geq 1000$  m.

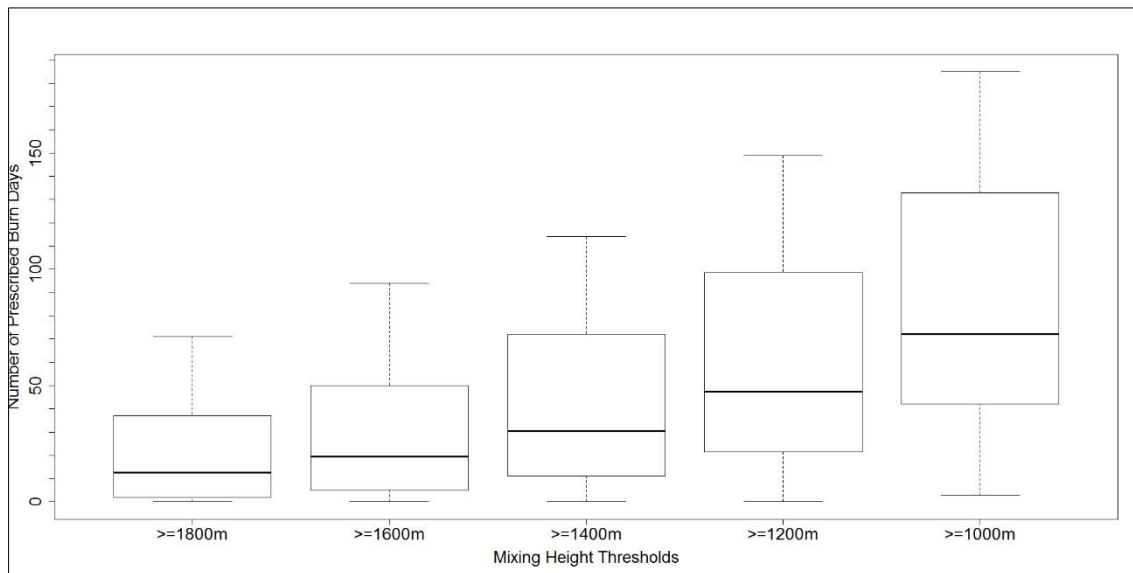


Figure 3.1 Box plots of annual prescribed burn days for Mississippi at 18z

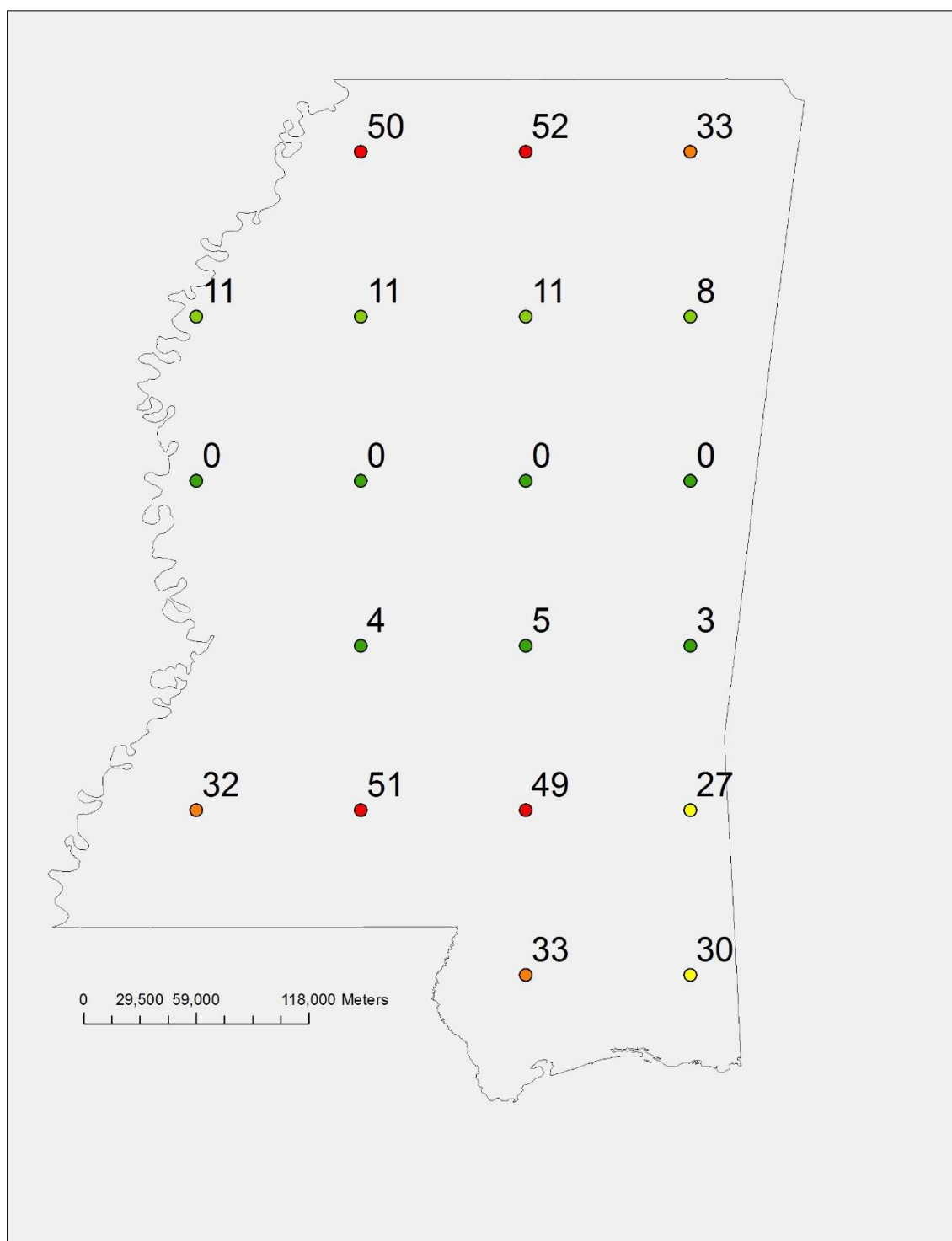


Figure 3.2 Map of the average annual prescribed burn days for Mississippi from 1980 to 2010 using mixing heights threshold of  $\geq 1800$  m

(using time 18z)



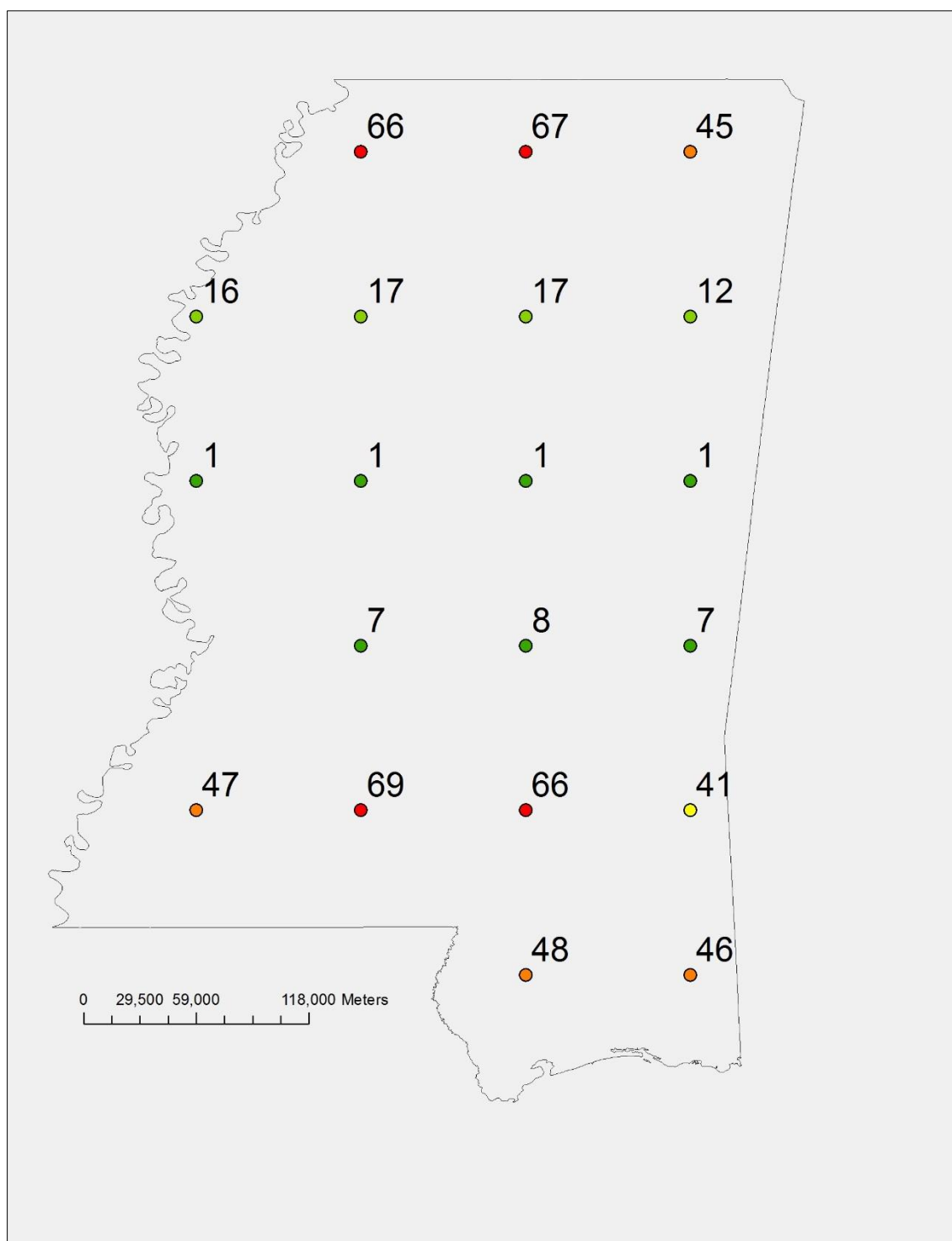


Figure 3.3 Map of the average annual prescribed burn days for Mississippi from 1980 to 2010 using mixing heights threshold of  $\geq 1600$  m

(using time 18z)

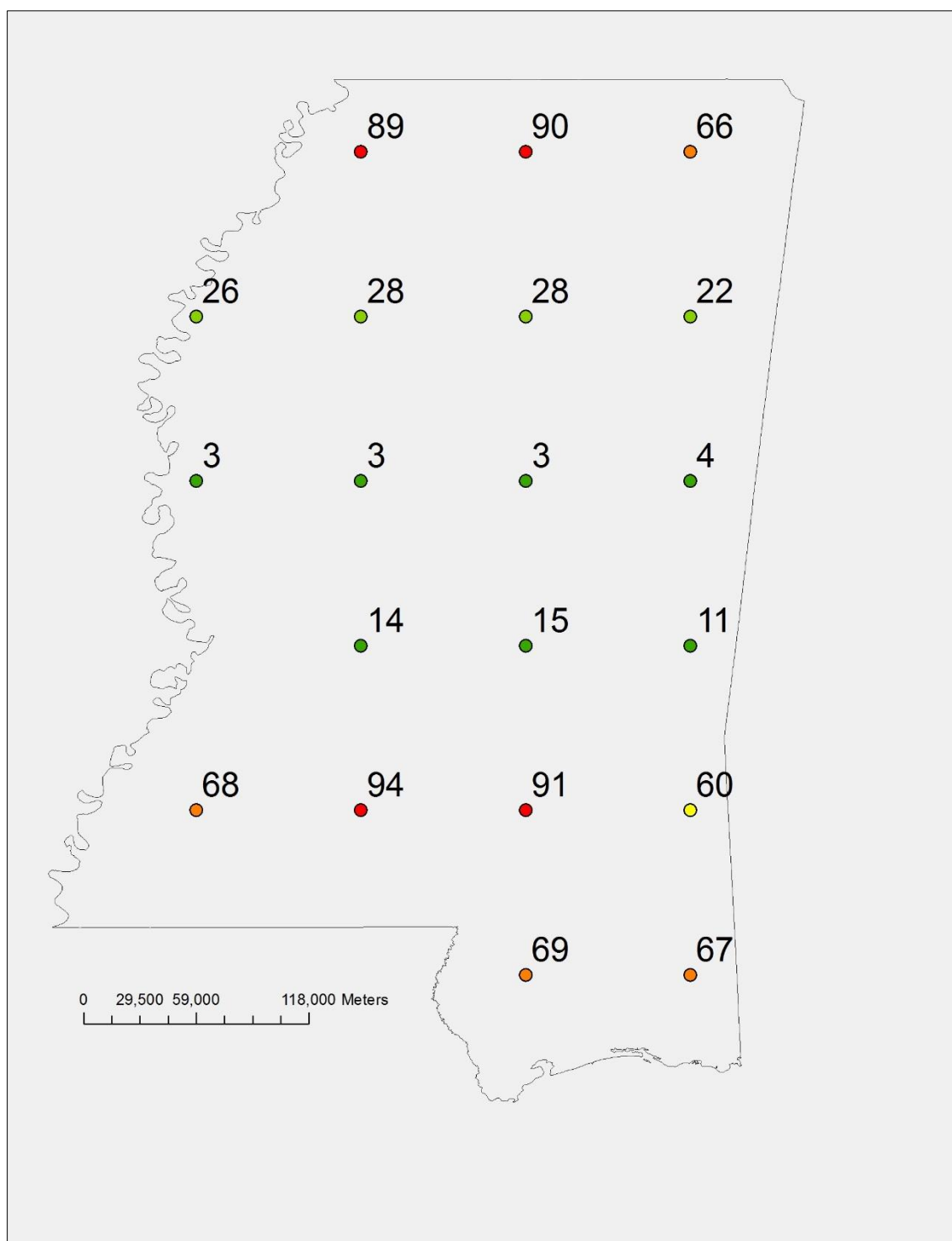


Figure 3.4 Map of the average annual prescribed burn days for Mississippi from 1980 to 2010 using mixing heights threshold of  $\geq 1400$  m

(using time 18z)

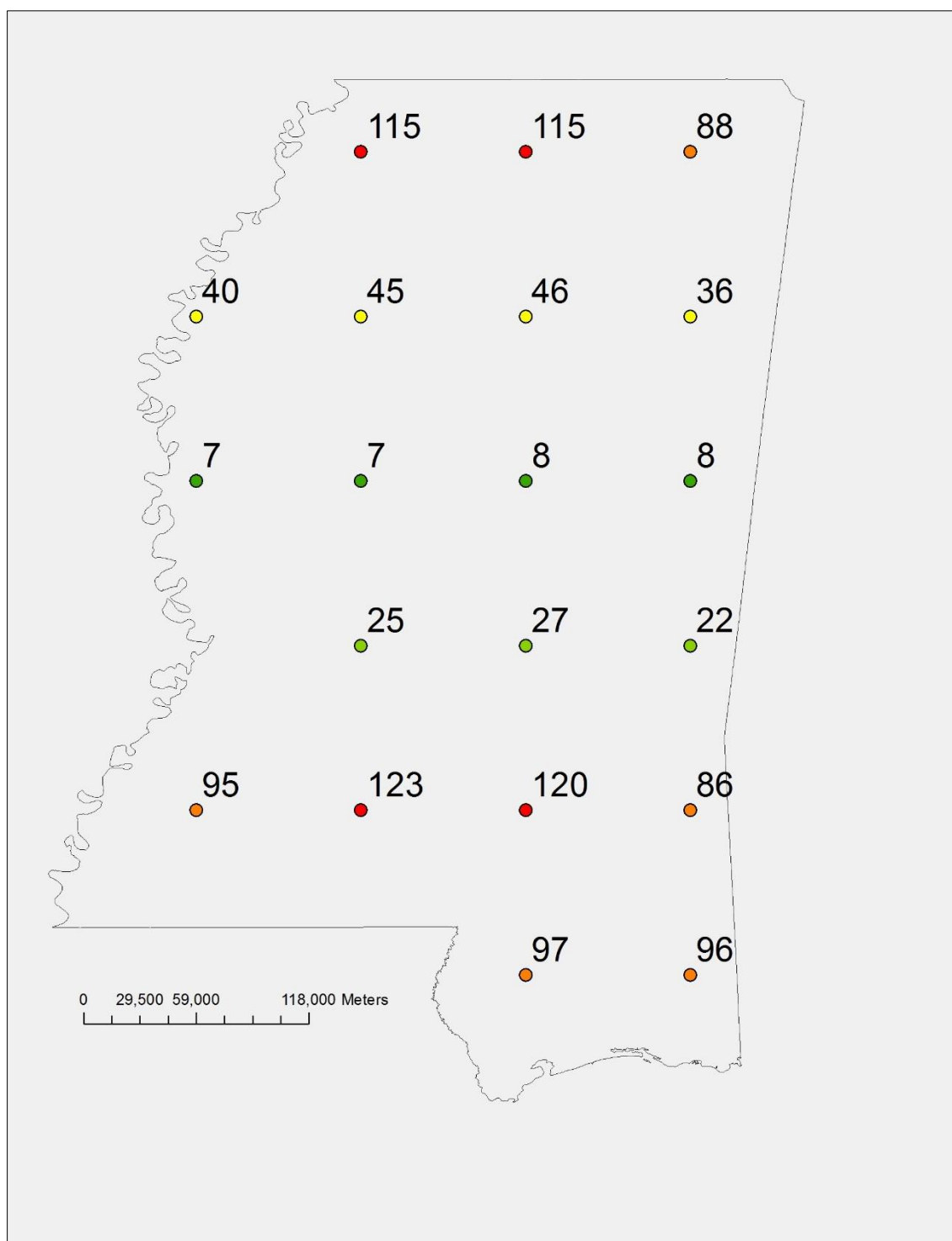


Figure 3.5 Map of the average annual prescribed burn days for Mississippi from 1980 to 2010 using mixing heights threshold of  $\geq 1200$  m

(using time 18z)

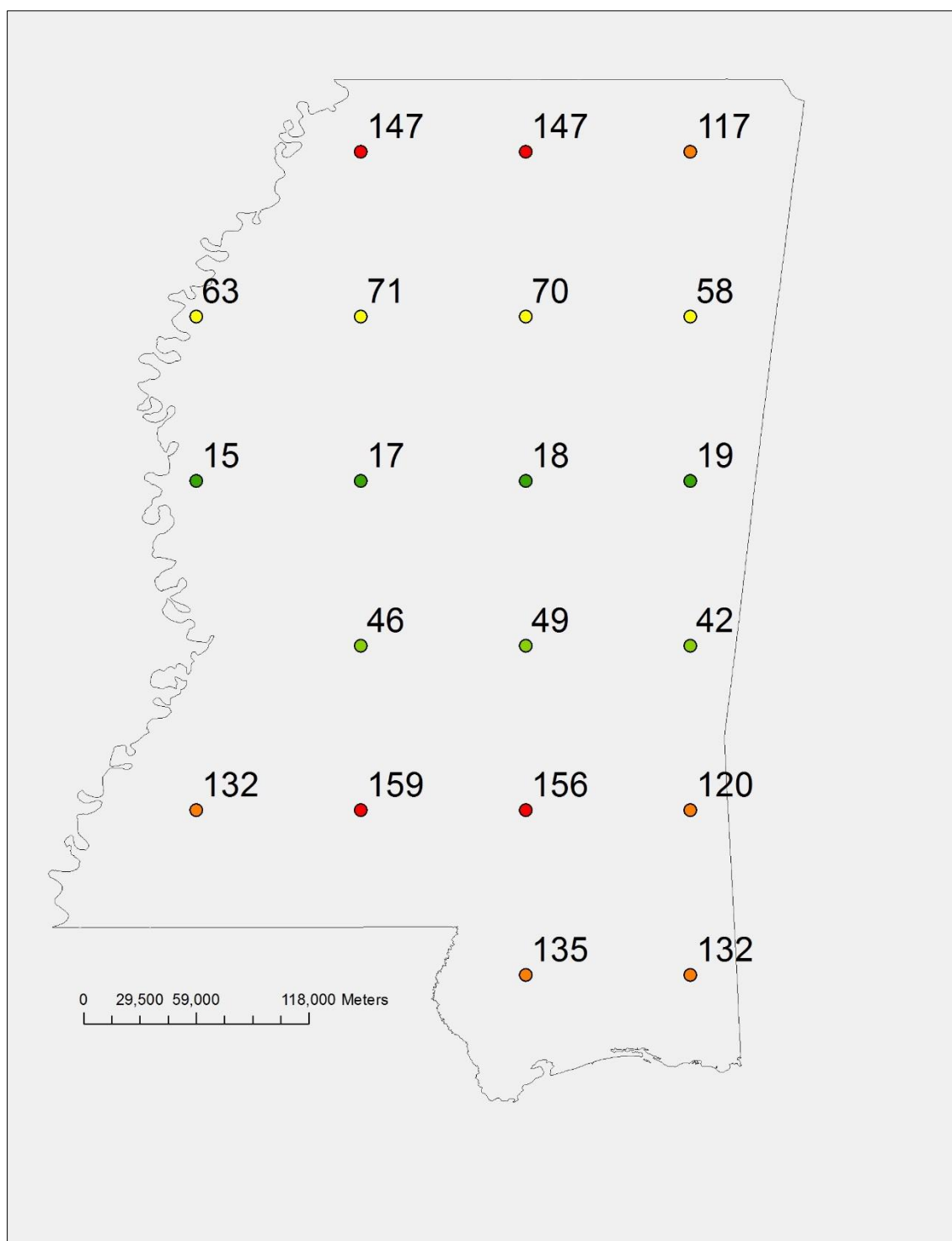


Figure 3.6 Map of the average annual prescribed burn days for Mississippi from 1980 to 2010 using mixing heights threshold of  $\geq 1000$  m

(using time 18z)

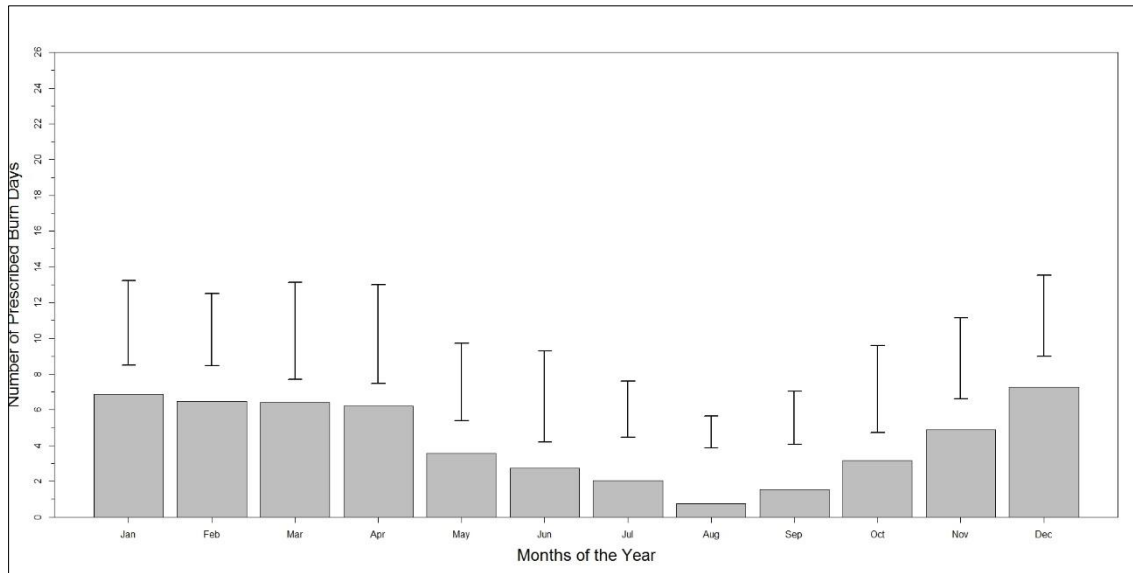


Figure 3.7 Average monthly number ( $\pm$ SD) of prescribed burn days in northern Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1800$  m (using time 18z)

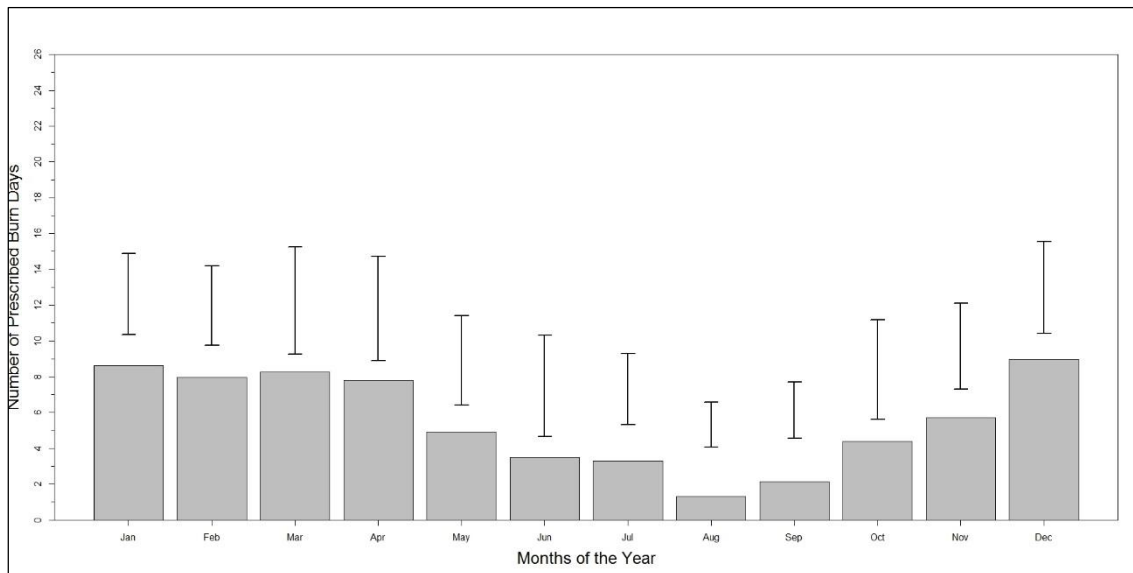


Figure 3.8 Average monthly number ( $\pm$ SD) of prescribed burn days in northern Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1600$  m (using time 18z)

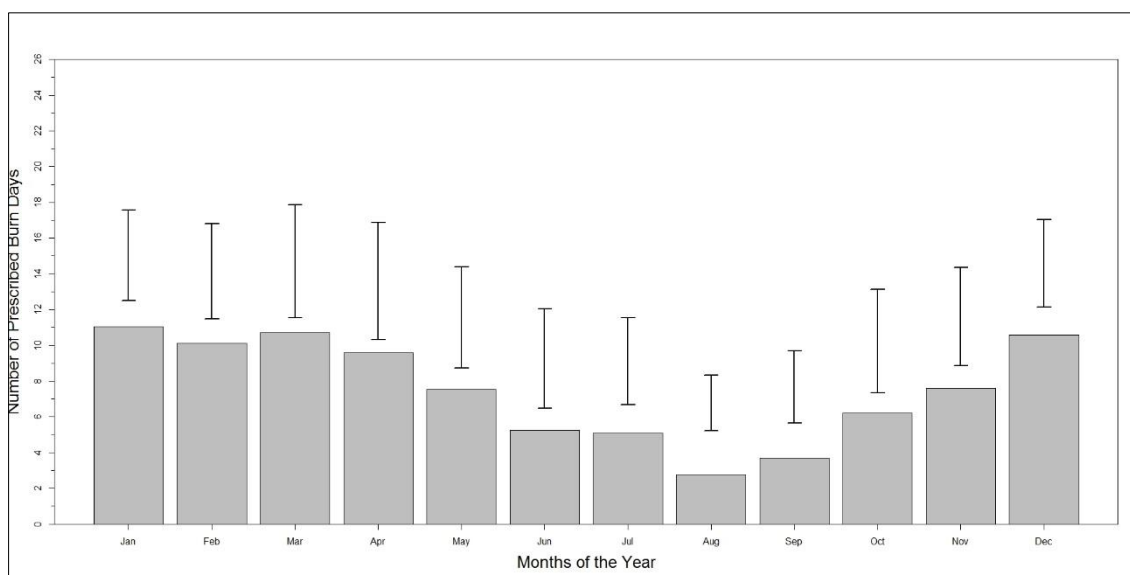


Figure 3.9 Average monthly number ( $\pm$ SD) of prescribed burn days in northern Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1400$  m (using time 18z)

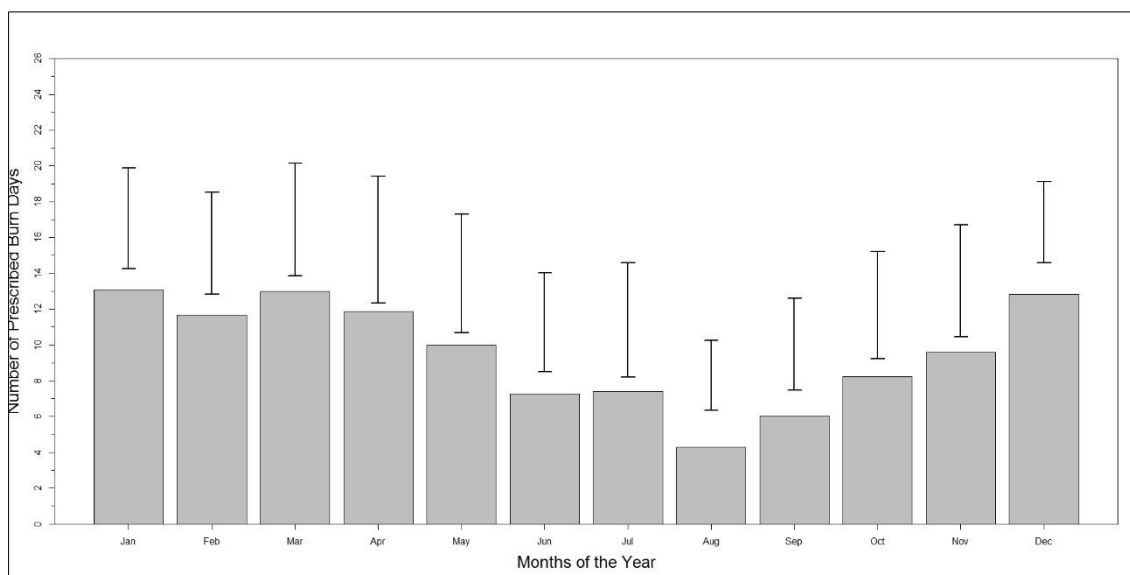


Figure 3.10 Average monthly number ( $\pm$ SD) of prescribed burn days in northern Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1200$  m (using time 18z)

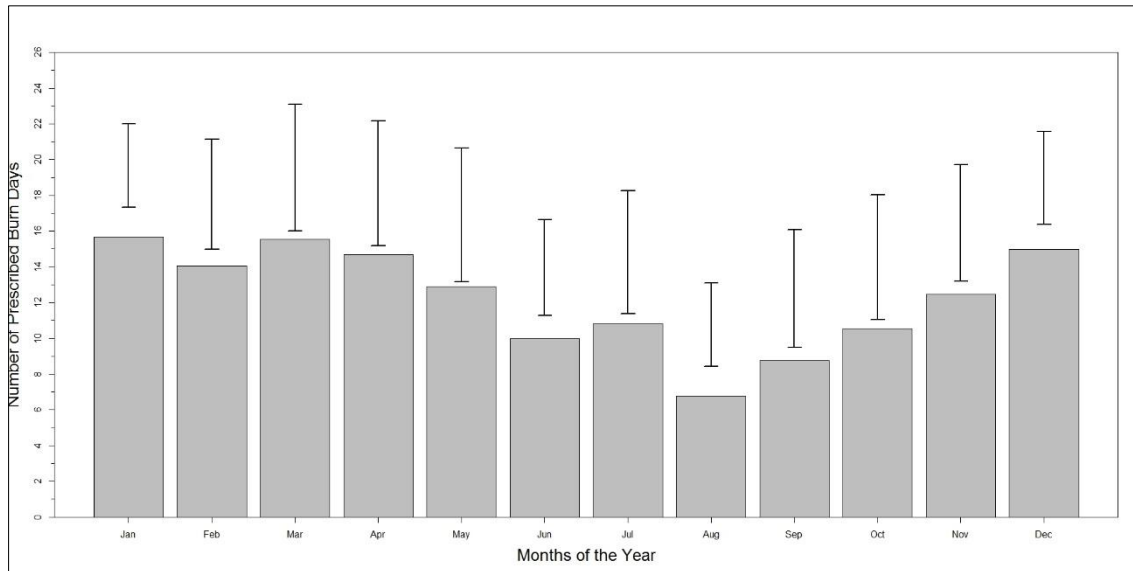


Figure 3.11 Average monthly number ( $\pm$ SD) of prescribed burn days in northern Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1000$  m (using time 18z)

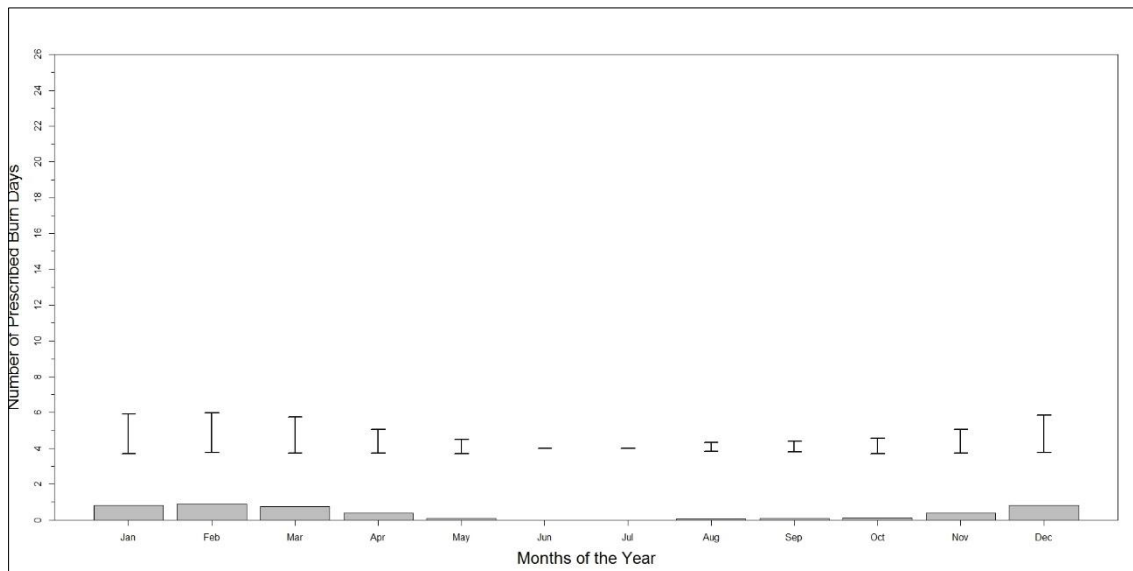


Figure 3.12 Average monthly number ( $\pm$ SD) of prescribed burn days in central Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1800$  m (using time 18z)

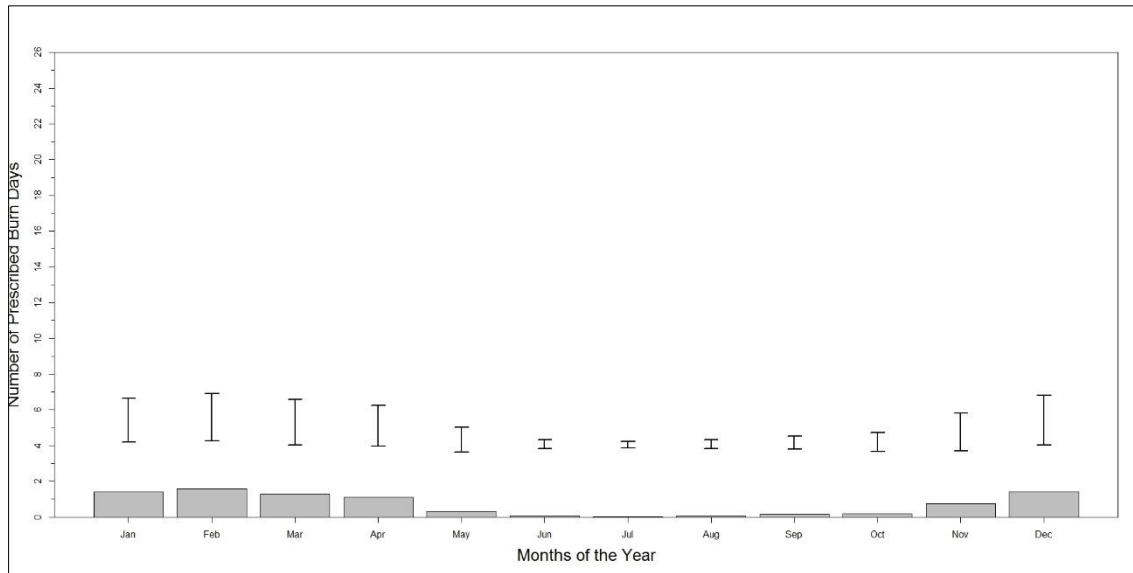


Figure 3.13 Average monthly number ( $\pm$ SD) of prescribed burn days in central Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1600$  m (using time 18z)

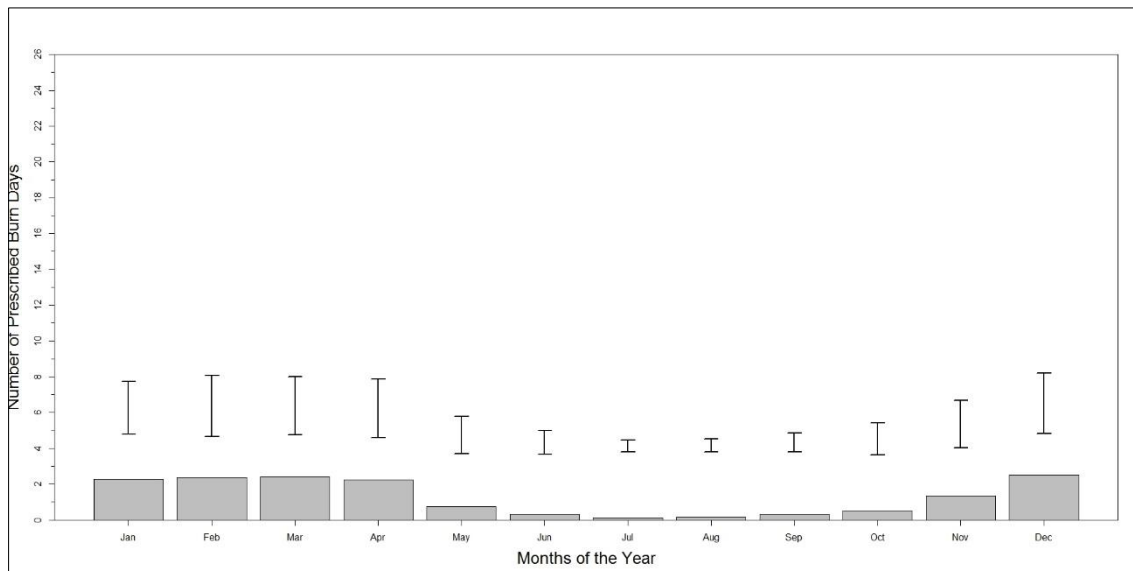


Figure 3.14 Average monthly number ( $\pm$ SD) of prescribed burn days in central Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1400$  m (using time 18z)



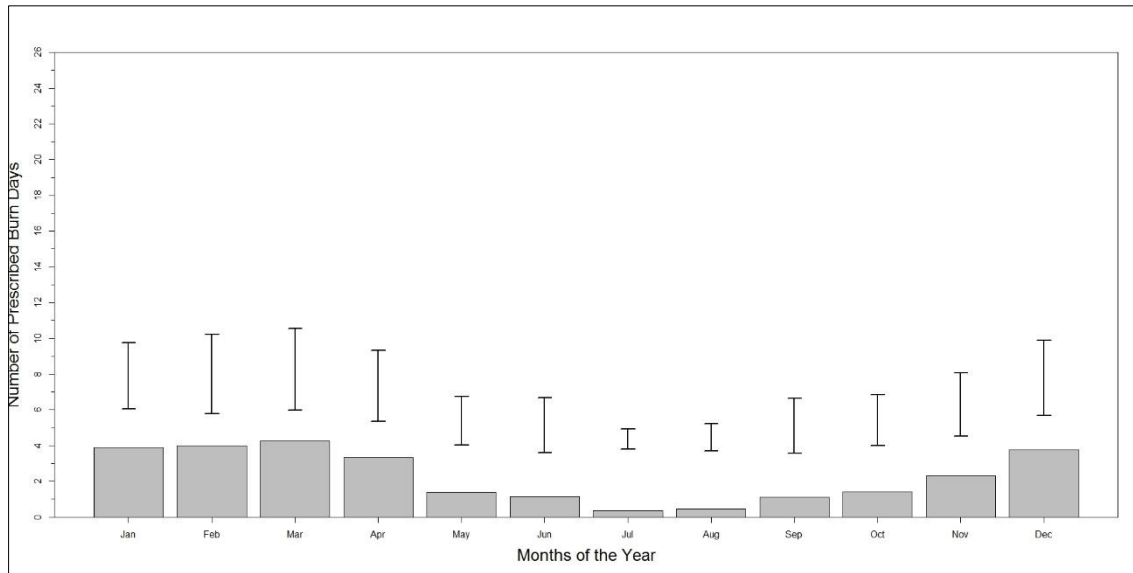


Figure 3.15 Average monthly number ( $\pm$ SD) of prescribed burn days in central Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1200$  m (using time 18z)

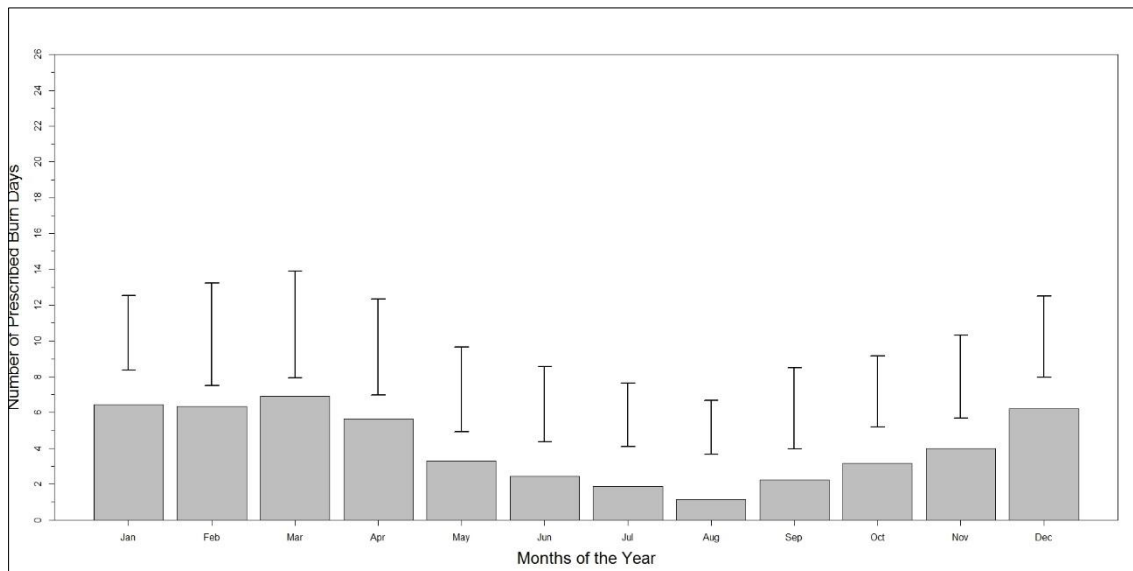


Figure 3.16 Average monthly number ( $\pm$ SD) of prescribed burn days in central Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1000$  m (using time 18z)

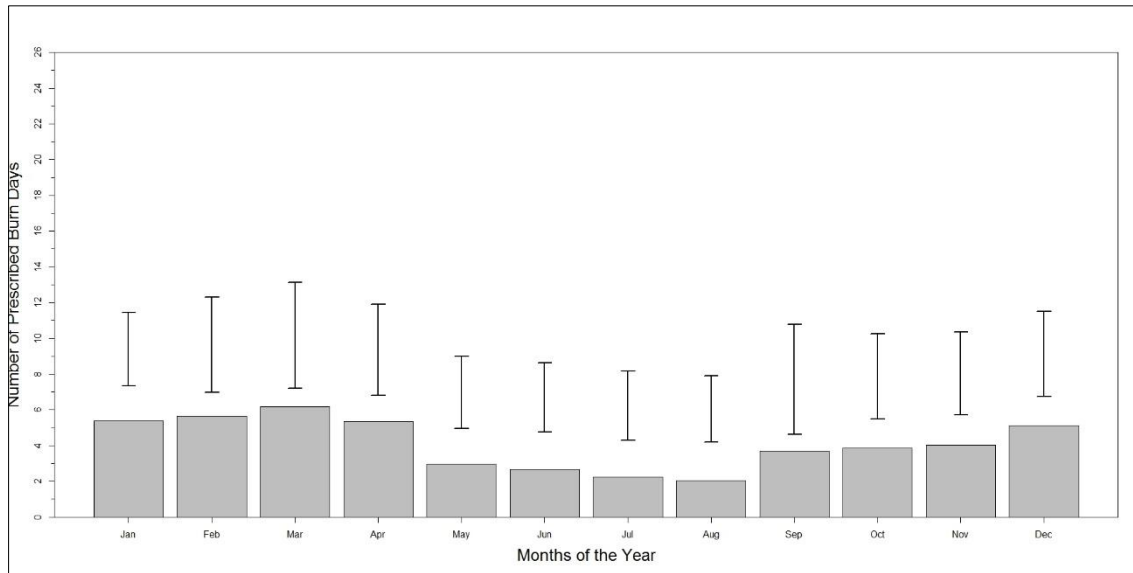


Figure 3.17 Average monthly number ( $\pm$ SD) of prescribed burn days in southern Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1800$  m (using time 18z)

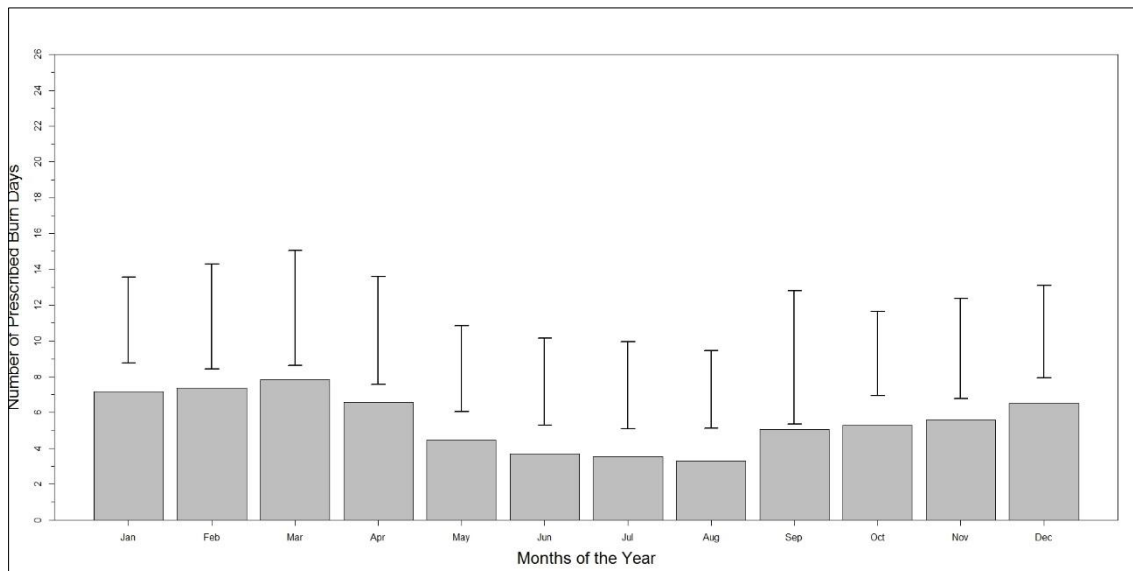


Figure 3.18 Average monthly number ( $\pm$ SD) of prescribed burn days in southern Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1600$  m (using time 18z)

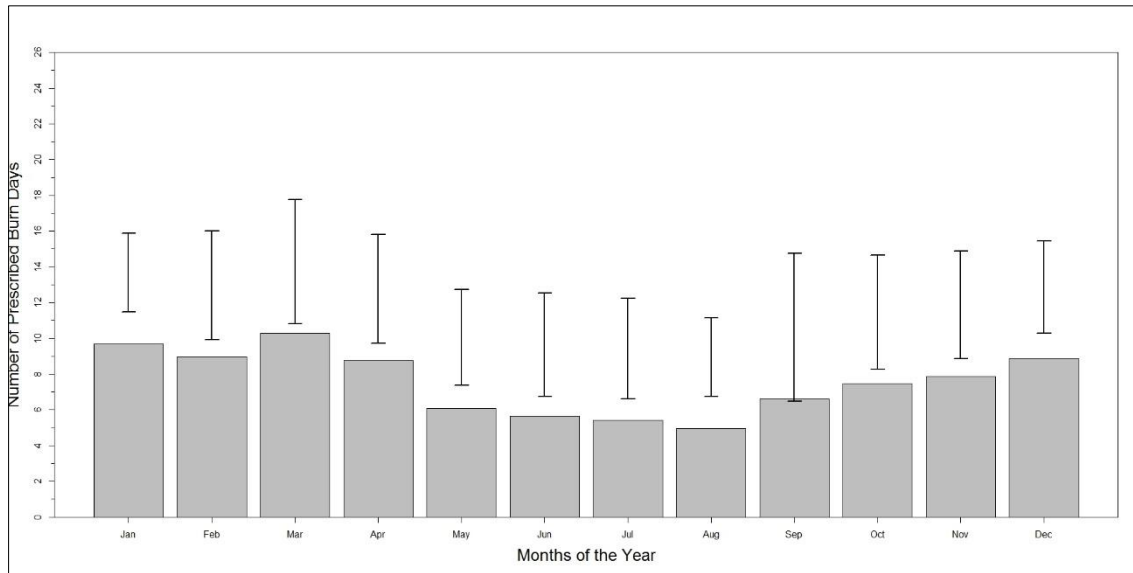


Figure 3.19 Average monthly number ( $\pm$ SD) of prescribed burn days in southern Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1400$  m (using time 18z)

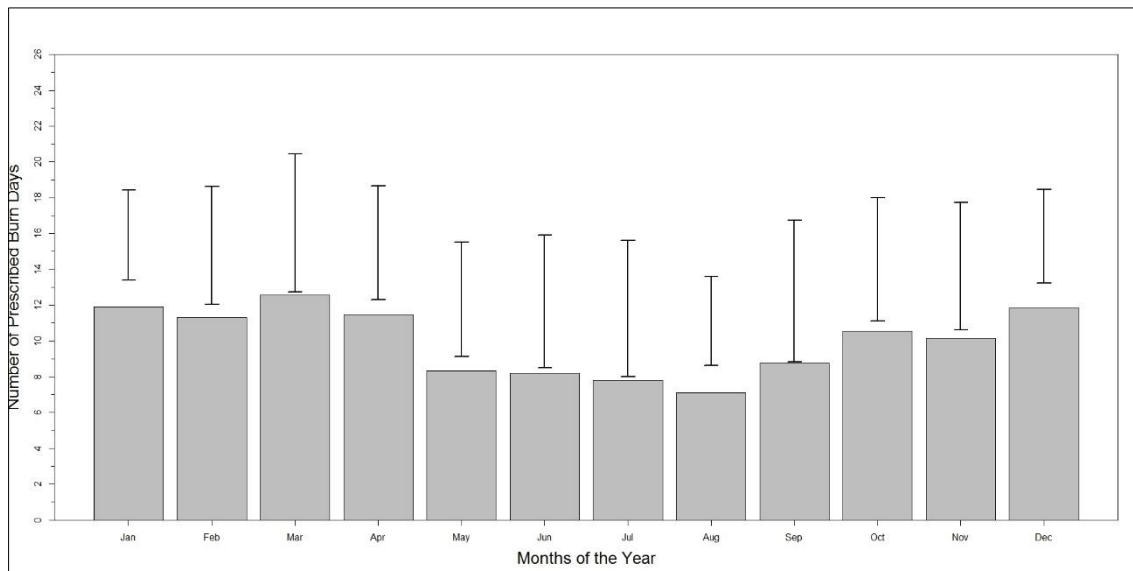


Figure 3.20 Average monthly number ( $\pm$ SD) of prescribed burn days in southern Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1200$  m (using time 18z)

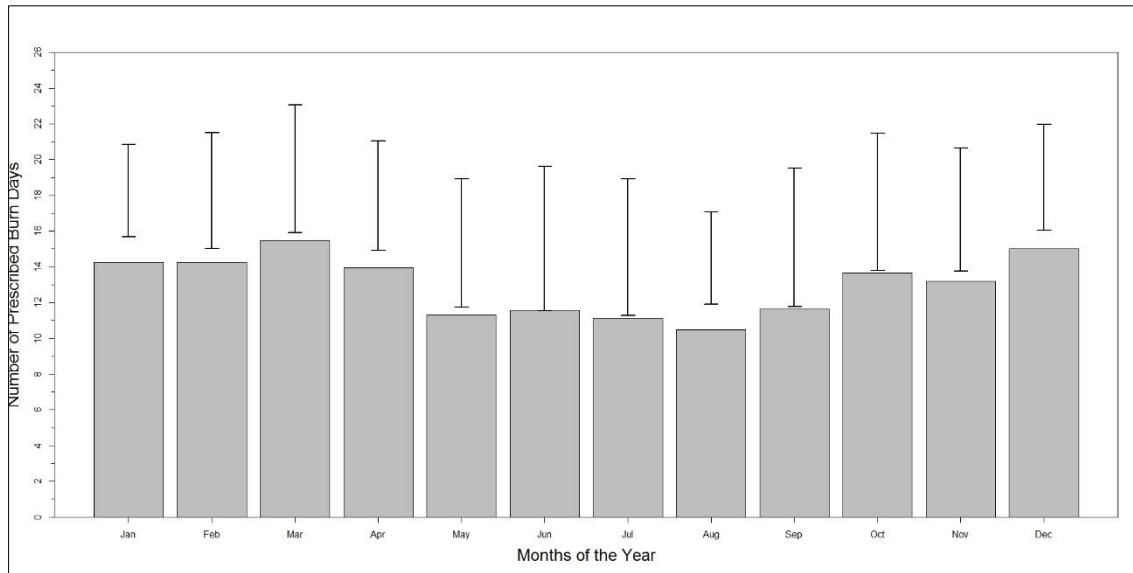


Figure 3.21 Average monthly number ( $\pm$ SD) of prescribed burn days in southern Mississippi from 1980-2010 with a mixing height threshold of  $\geq 1000$  m (using time 18z)

## CHAPTER IV

### FLORIDA RESULTS

#### 4.1 Overall

Prescribed burn days exhibited a contrast between the panhandle, central and southern Florida. Annual prescribed burn days ranged from 0 to 180 days for the 30 year period (Figure 4.1). Looking at  $\geq 1800$  m mixing heights, average annual prescribed burn days ranged from 2 to 42 (Figure 4.2). Using  $\geq 1600$  m mixing heights, average annual prescribed burn days ranged from 4 to 62 (Figure 4.3). Looking at  $\geq 1400$  m mixing heights, average annual prescribed burn days ranged from 11 to 84 (Figure 4.4). Using  $\geq 1200$  m mixing heights, average annual prescribed burn days ranged from 26 to 113 (Figure 4.5). Looking at  $\geq 1000$  m mixing heights, average annual prescribed burn days ranged from 51 to 148 (Figure 4.6). Throughout all of these mixing heights, the Florida Panhandle had experienced relatively moderate number of days. Central Florida experienced relatively high number of days and southern Florida experienced relatively low number of days.

#### 4.2 Seasonality

Each area of Florida experienced a difference in the amount of prescribed burn days based on time of year. For the Florida panhandle the highest amount of prescribed burn days occurred from September through April. Prescribed burn days were minimal

from May through August in the Florida panhandle (Figures 4.7–4.11). For most of the mixing heights central Florida had two distinctive seasons (Figures 4.12–4.16). The first season which occurred from March through April had relatively high prescribed burn days. The second season which occurred from June through September had relatively low prescribed burn days. Southern Florida had the highest amount of prescribed burn days from January through May (Figures 4.17–4.21). Prescribed burn days declined from June through November in southern Florida.

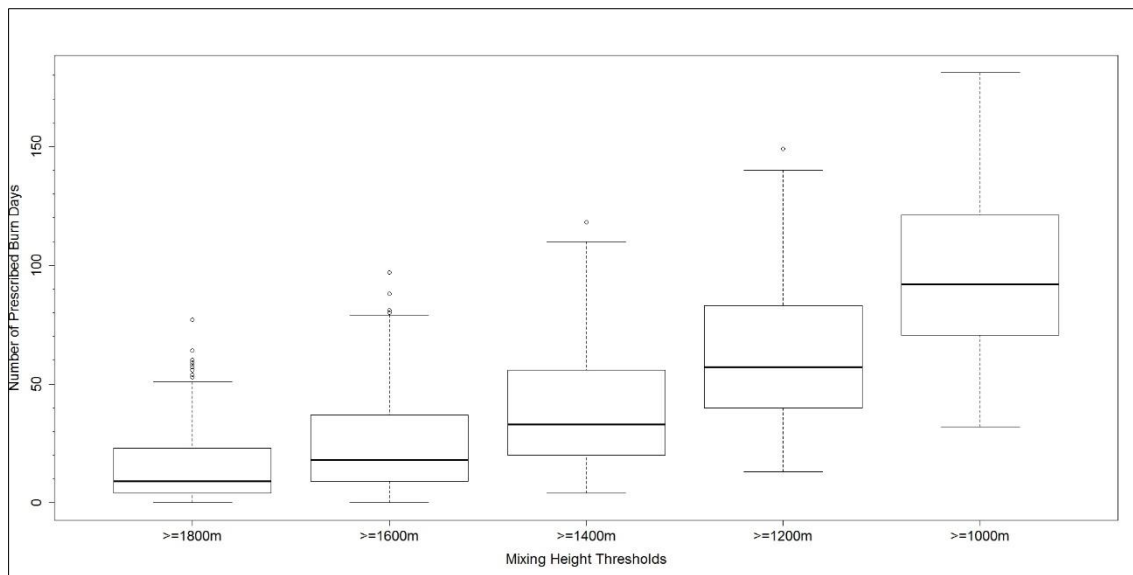


Figure 4.1 Box plots of annual prescribed burn days for Florida at 18z

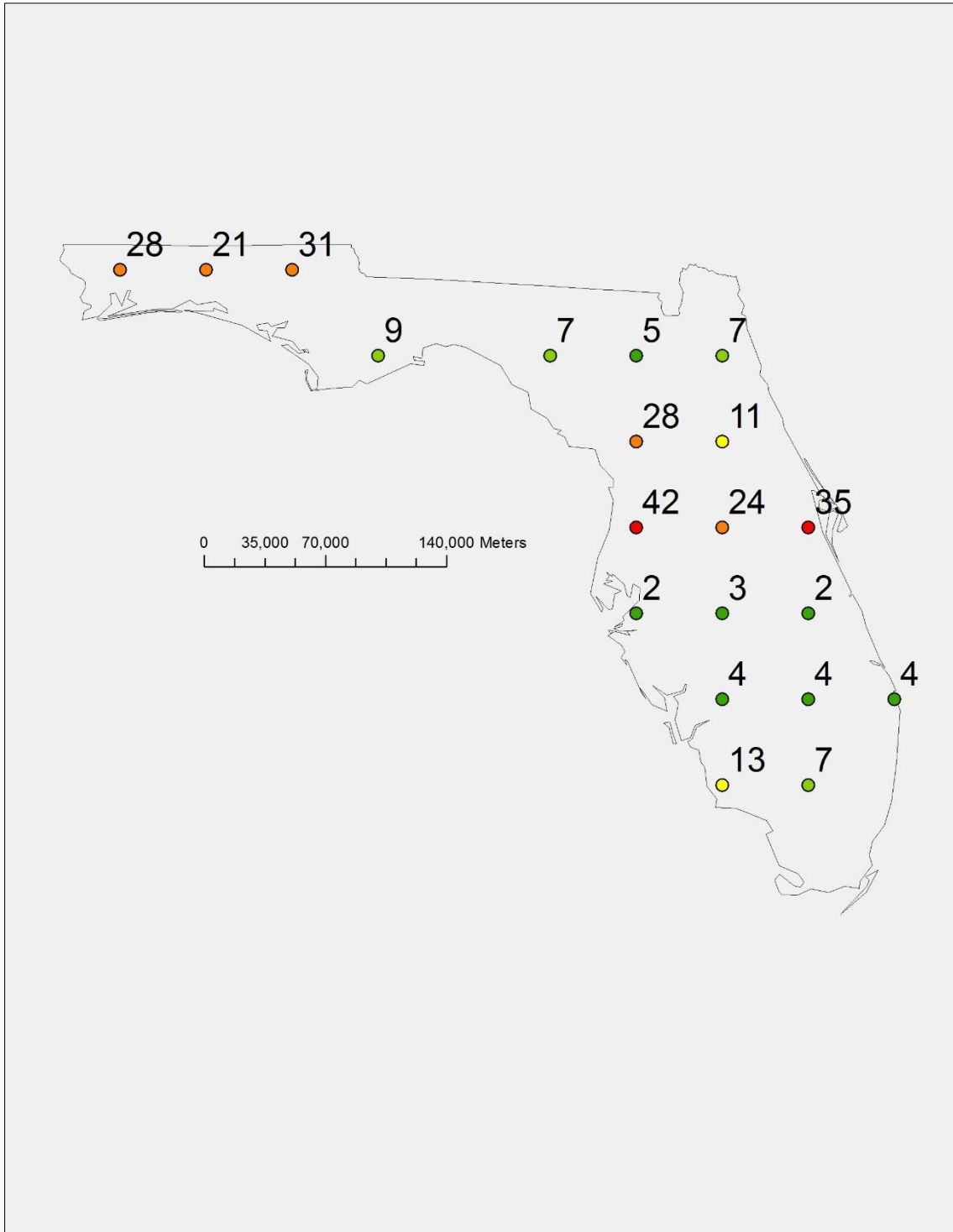


Figure 4.2 Map of the average annual prescribed burn days for Florida from 1980 to 2010 using mixing heights threshold of  $\geq 1800$  m  
(using time 18z)

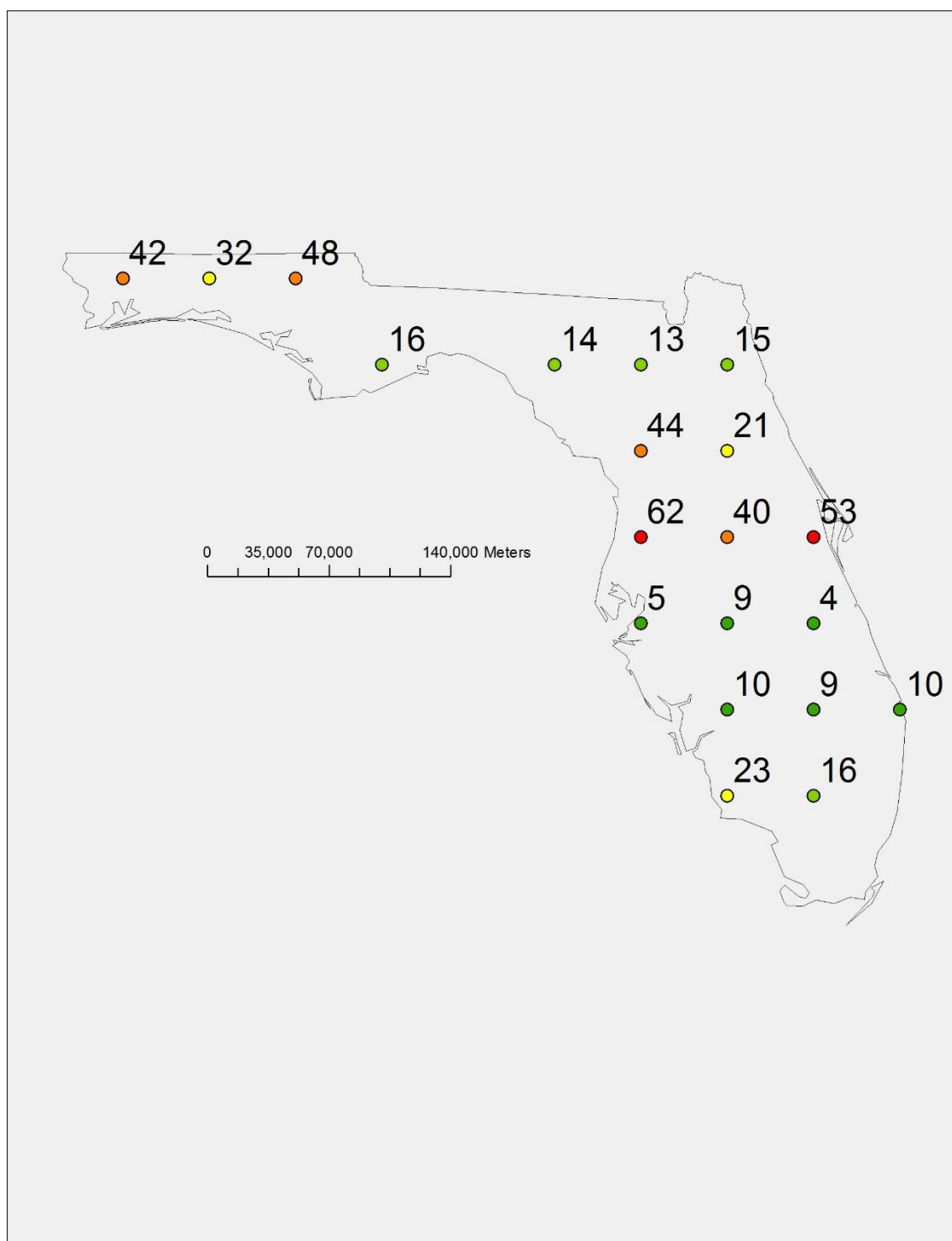


Figure 4.3 Map of the average annual prescribed burn days for Florida from 1980 to 2010 using mixing heights threshold of  $\geq 1600$  m

(using time 18z)



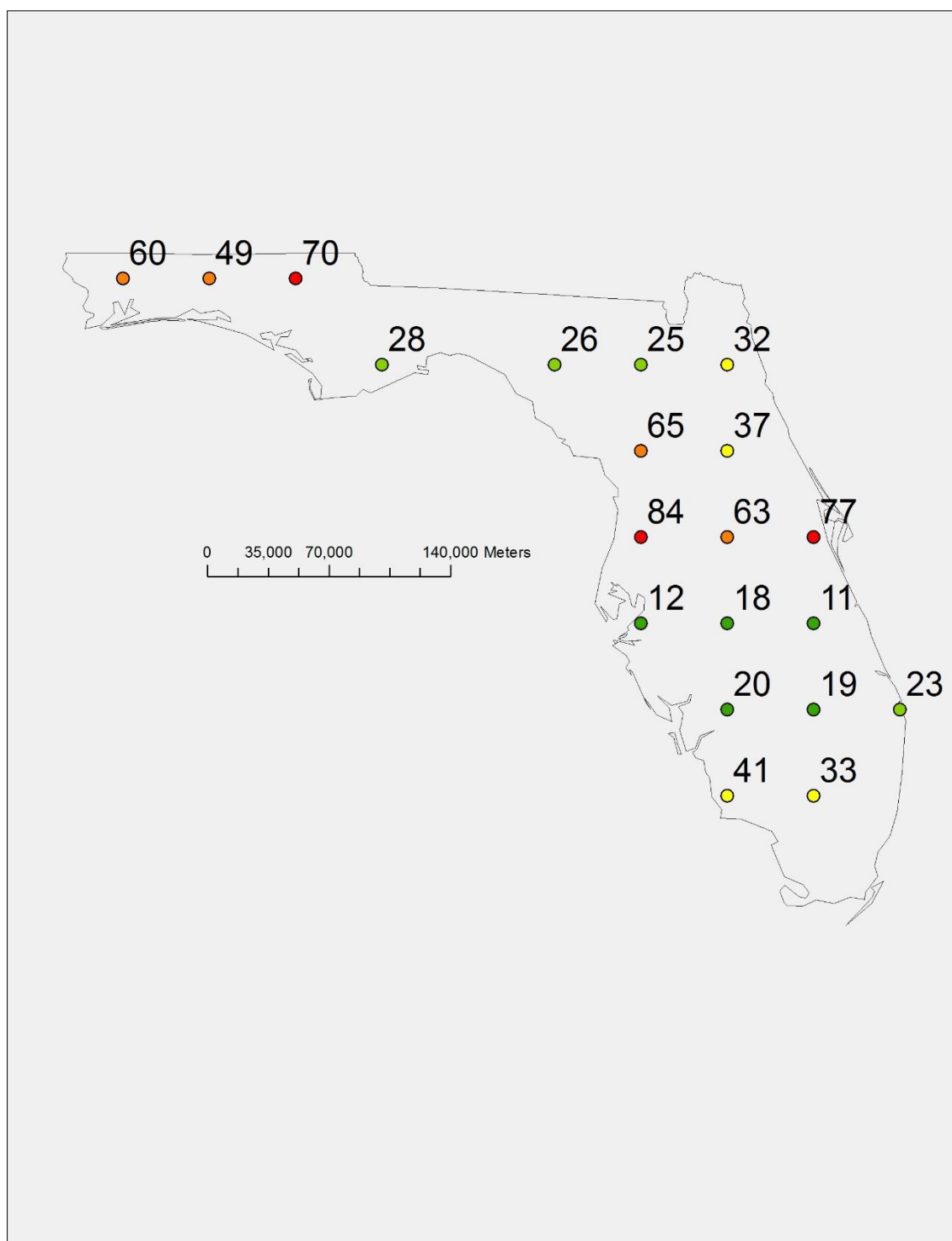


Figure 4.4 Map of the average annual prescribed burn days for Florida from 1980 to 2010 using mixing heights threshold of  $\geq 1400$  m

(using time 18z)

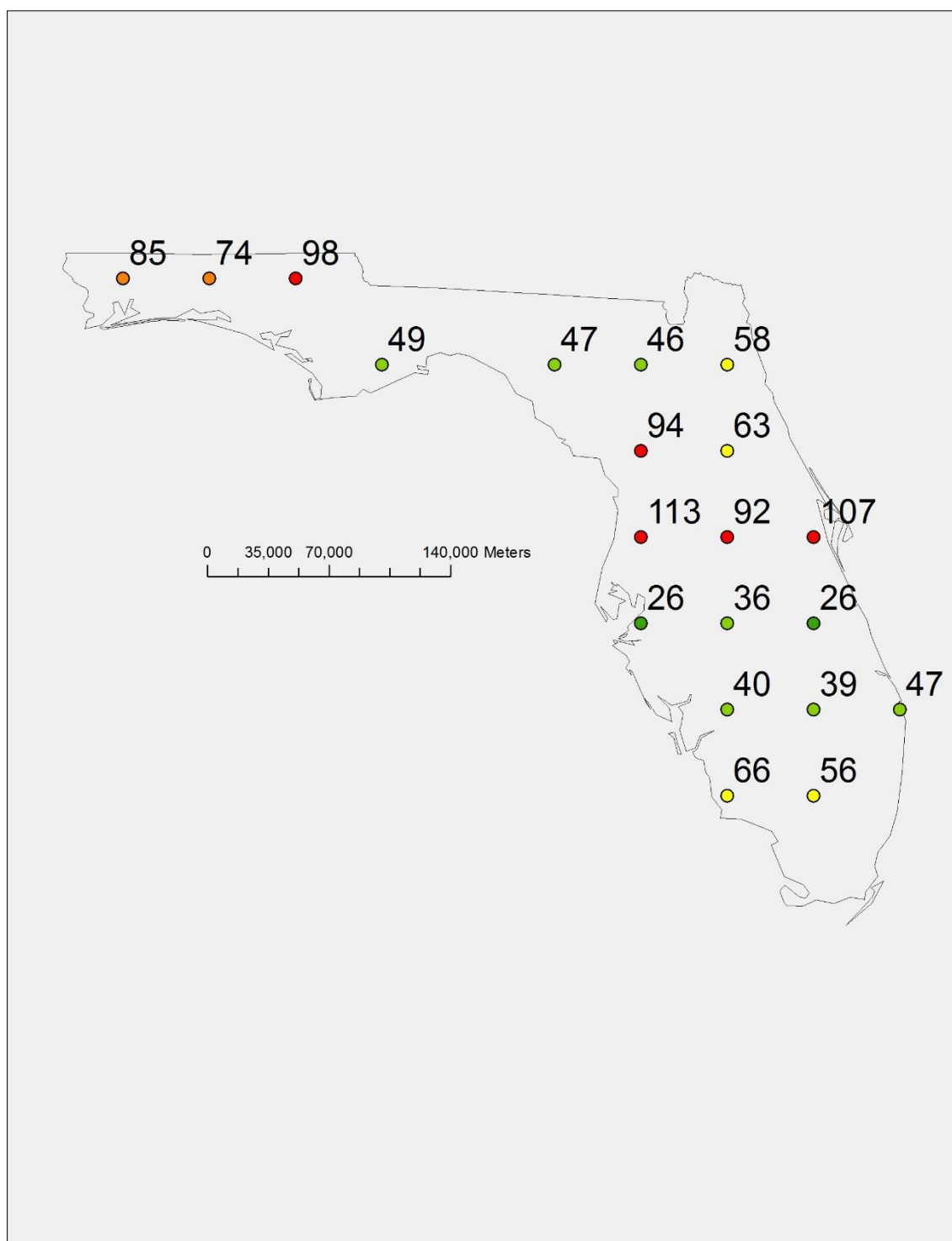


Figure 4.5 Map of the average annual prescribed burn days for Florida from 1980 to 2010 using mixing heights threshold of  $\geq 1200$  m

(using time 18z)

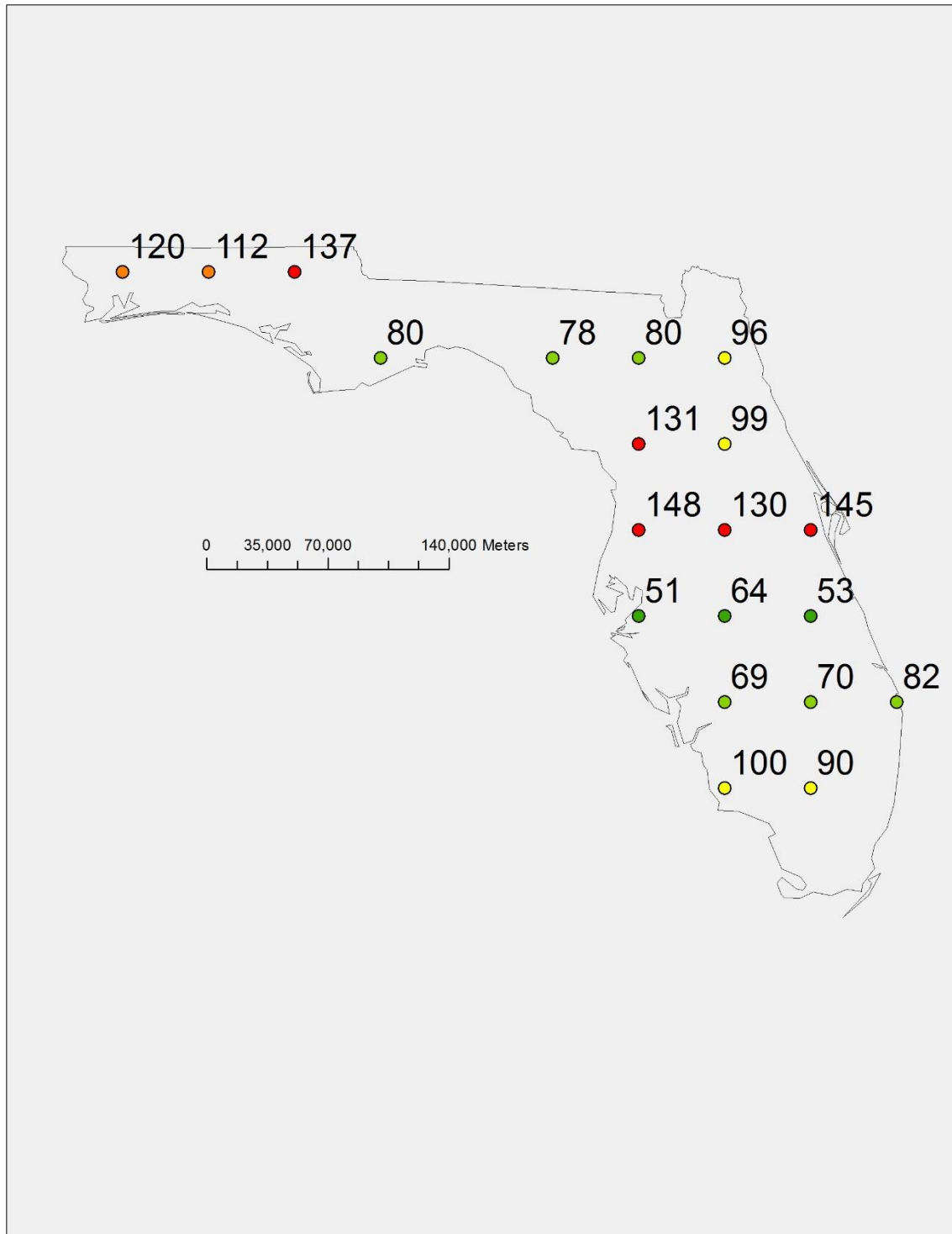


Figure 4.6 Map of the average annual prescribed burn days for Florida from 1980 to 2010 using mixing heights threshold of  $\geq 1000$  m  
(using time 18z)

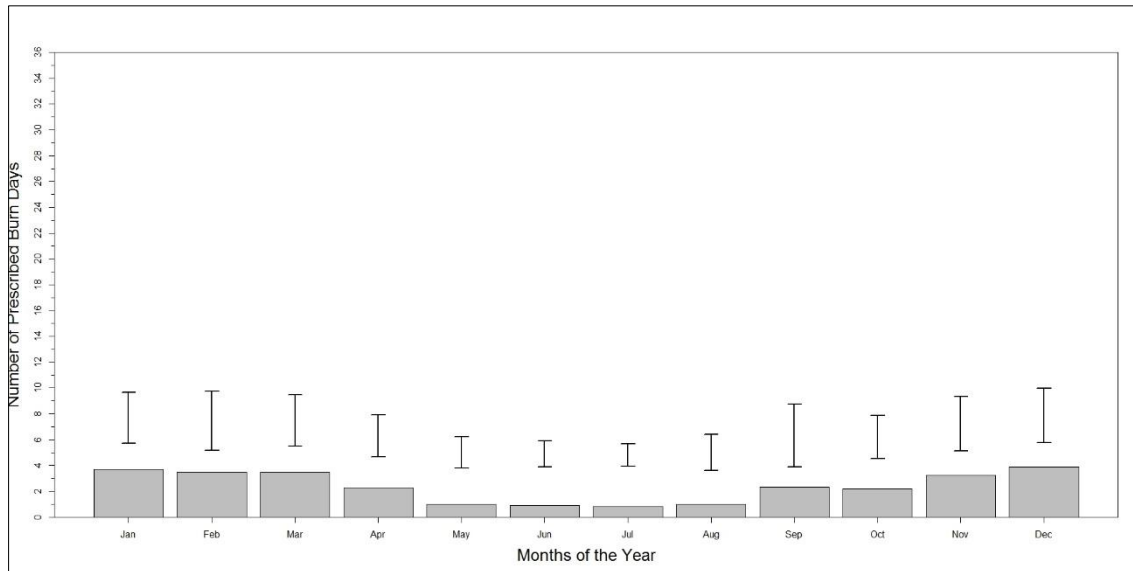


Figure 4.7 Average monthly number ( $\pm$ SD) of prescribed burn days in Florida Panhandle from 1980-2010 with a mixing height threshold of  $\geq 1800$  m (using time 18z)

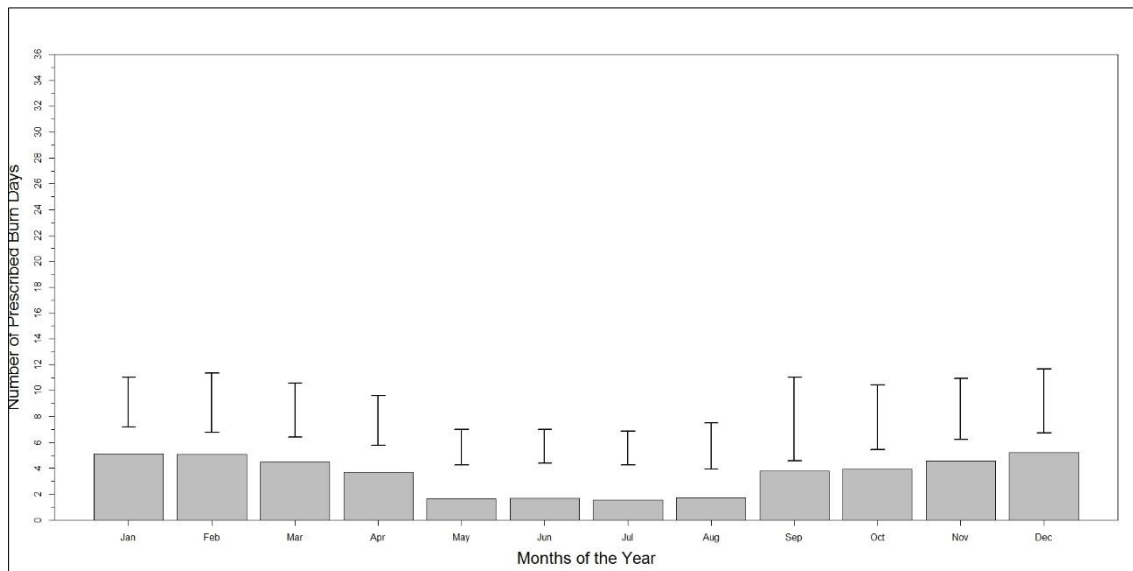


Figure 4.8 Average monthly number ( $\pm$ SD) of prescribed burn days in Florida Panhandle from 1980-2010 with a mixing height threshold of  $\geq 1600$  m (using time 18z)

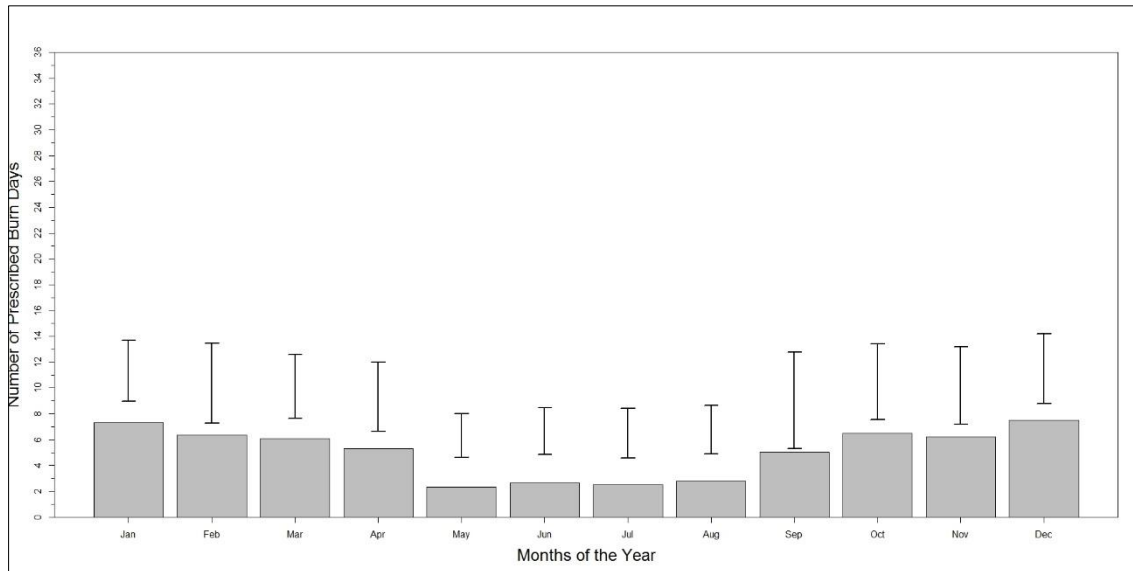


Figure 4.9 Average monthly number ( $\pm$ SD) of prescribed burn days in Florida Panhandle from 1980-2010 with a mixing height threshold of  $\geq 1400$  m (using time 18z)

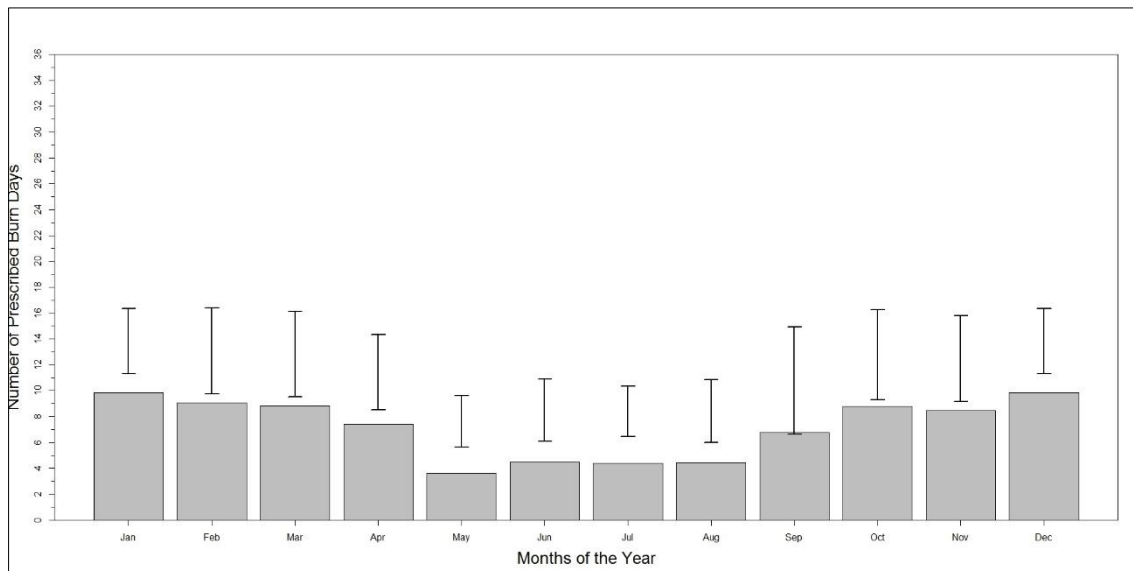


Figure 4.10 Average monthly number ( $\pm$ SD) of prescribed burn days in Florida Panhandle from 1980-2010 with a mixing height threshold of  $\geq 1200$  m (using time 18z)

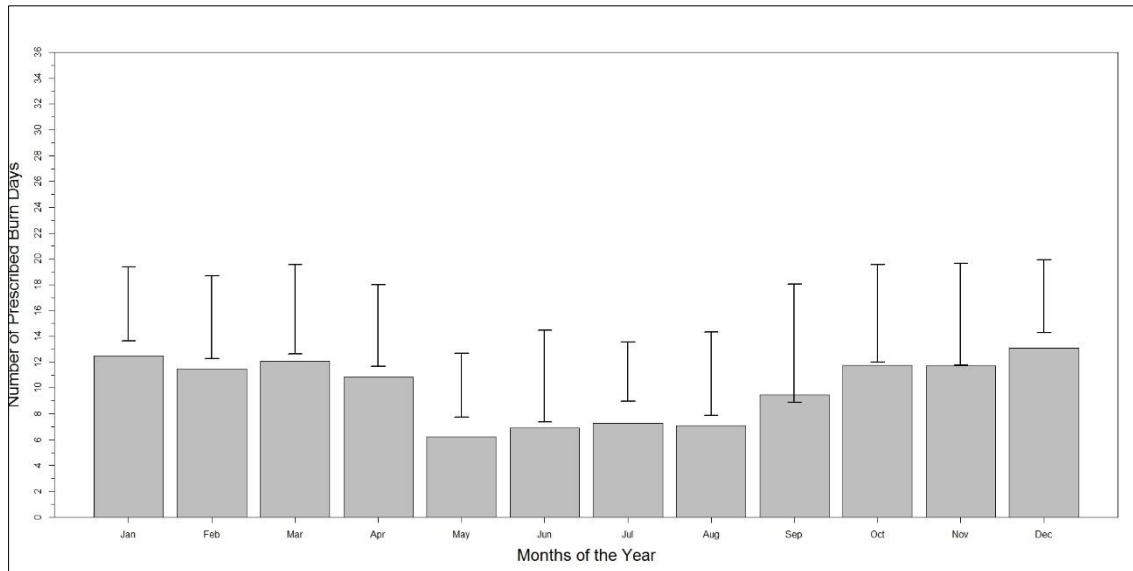


Figure 4.11 Average monthly number ( $\pm$ SD) of prescribed burn days in Florida Panhandle from 1980-2010 with a mixing height threshold of  $\geq 1000$  m (using time 18z)

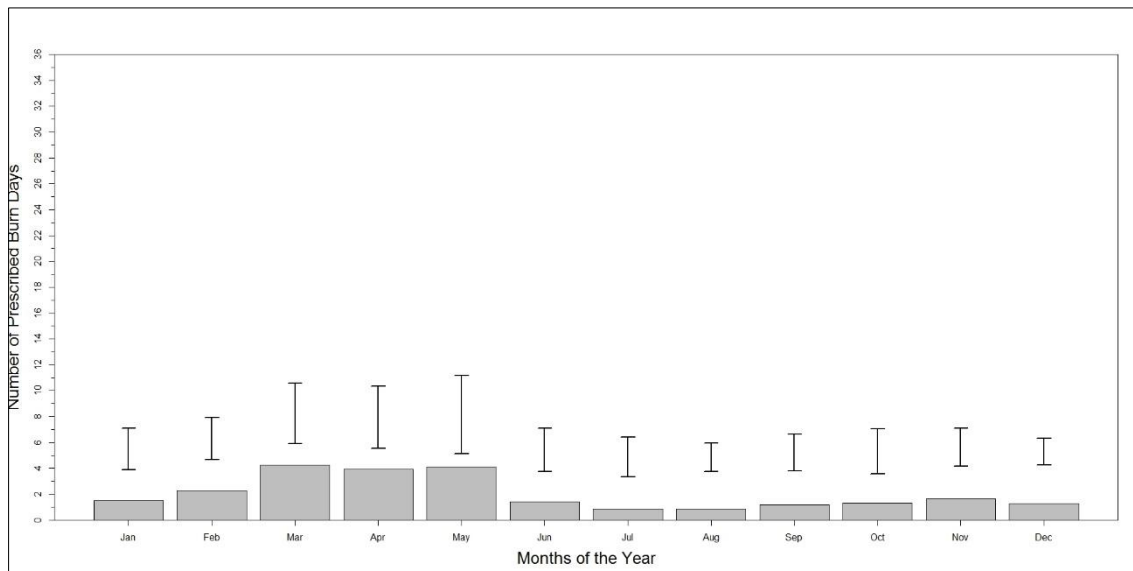


Figure 4.12 Average monthly number ( $\pm$ SD) of prescribed burn days in central Florida from 1980-2010 with a mixing height threshold of  $\geq 1800$  m (using time 18z)

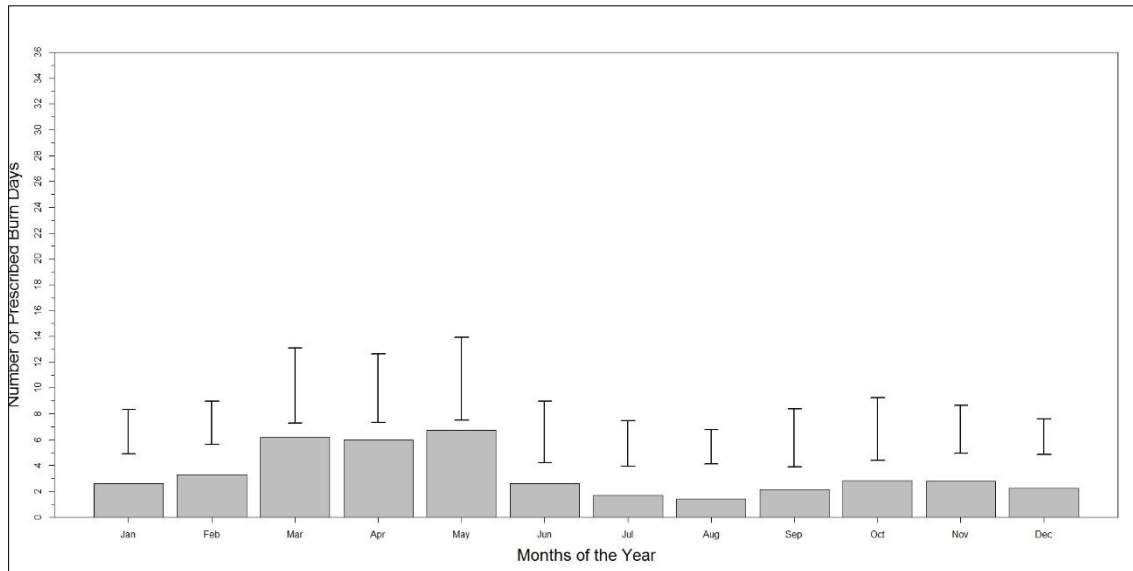


Figure 4.13 Average monthly number ( $\pm$ SD) of prescribed burn days in central Florida from 1980-2010 with a mixing height threshold of  $\geq 1600$  m  
(using time 18z)

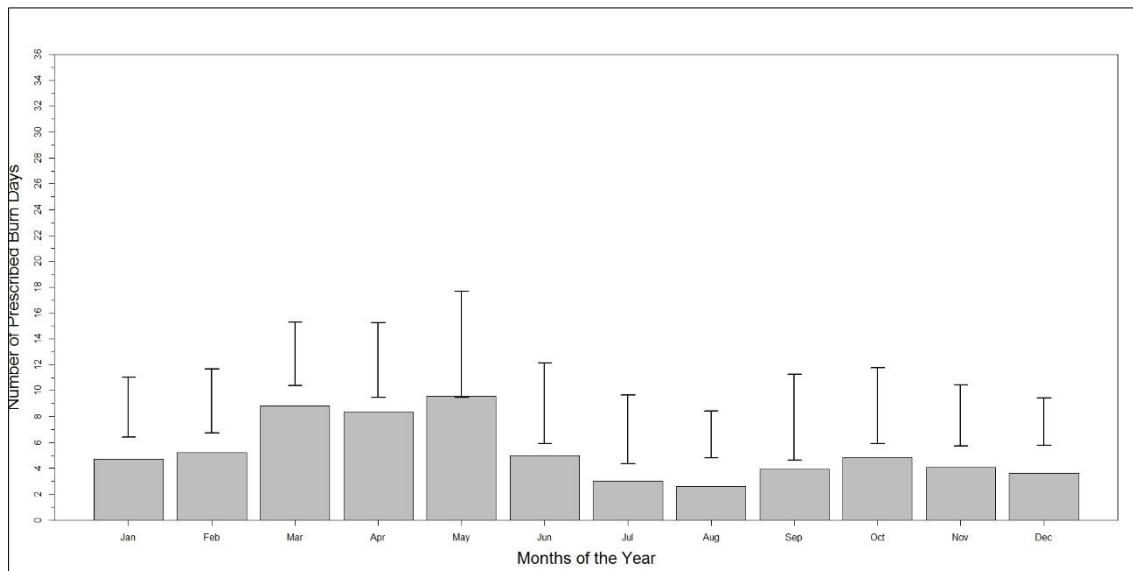


Figure 4.14 Average monthly number ( $\pm$ SD) of prescribed burn days in central Florida from 1980-2010 with a mixing height threshold of  $\geq 1400$  m  
(using time 18z)

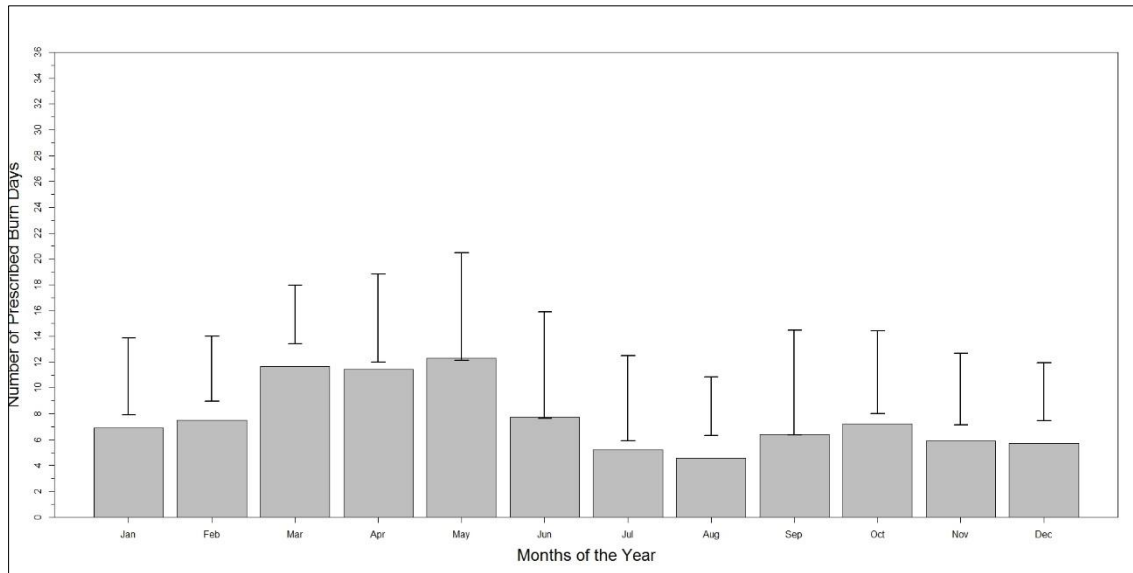


Figure 4.15 Average monthly number ( $\pm$ SD) of prescribed burn days in central Florida from 1980-2010 with a mixing height threshold of  $\geq 1200$  m (using time 18z)

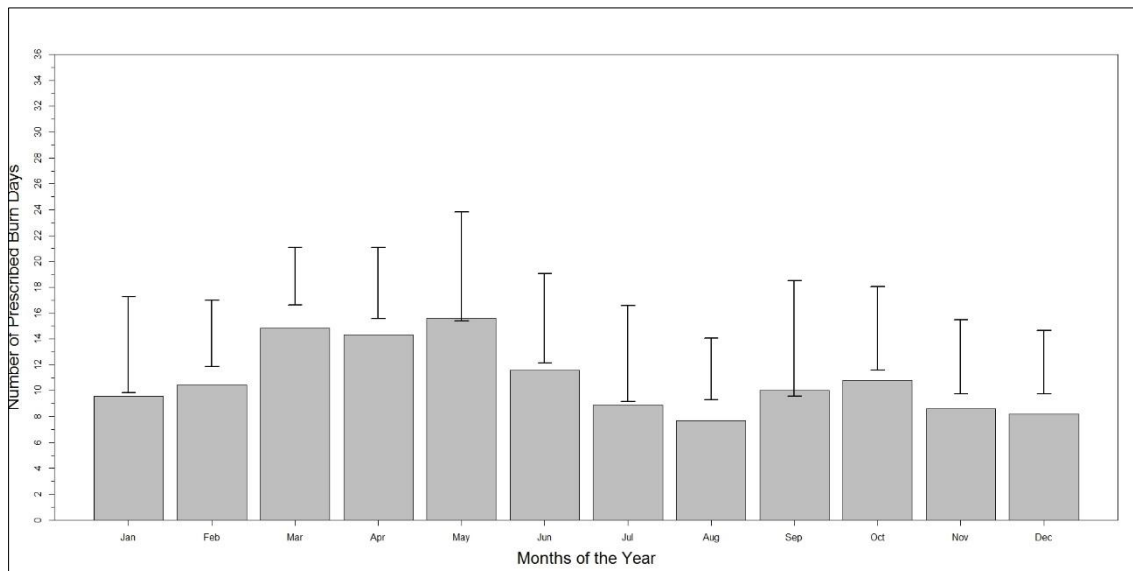


Figure 4.16 Average monthly number ( $\pm$ SD) of prescribed burn days in central Florida from 1980-2010 with a mixing height threshold of  $\geq 1000$  m (using time 18z)



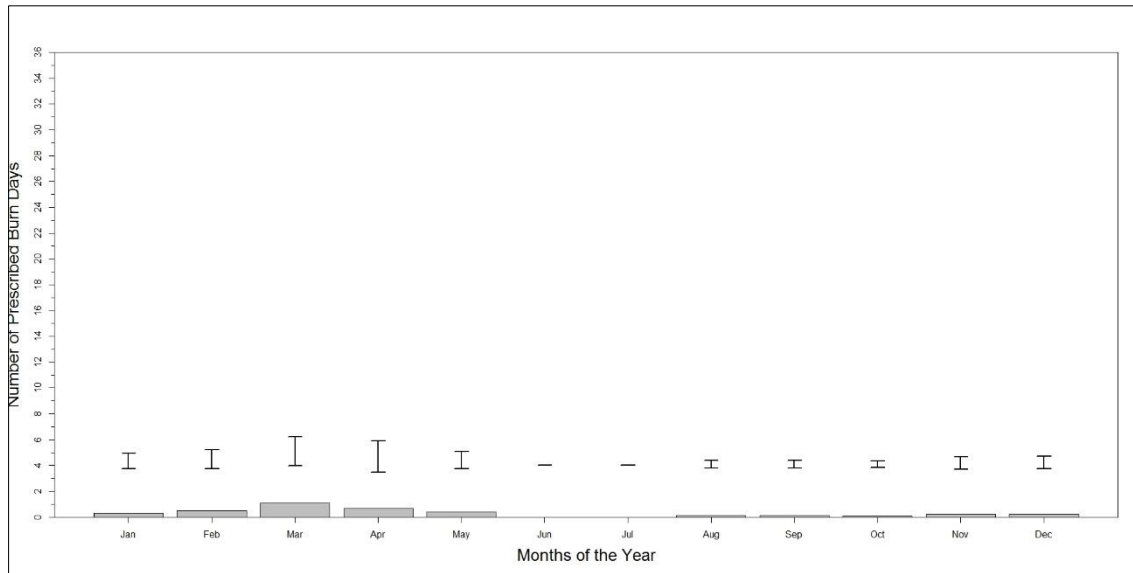


Figure 4.17 Average monthly number ( $\pm$ SD) of prescribed burn days in southern Florida from 1980-2010 with a mixing height threshold of  $\geq 1800$  m (using time 18z)

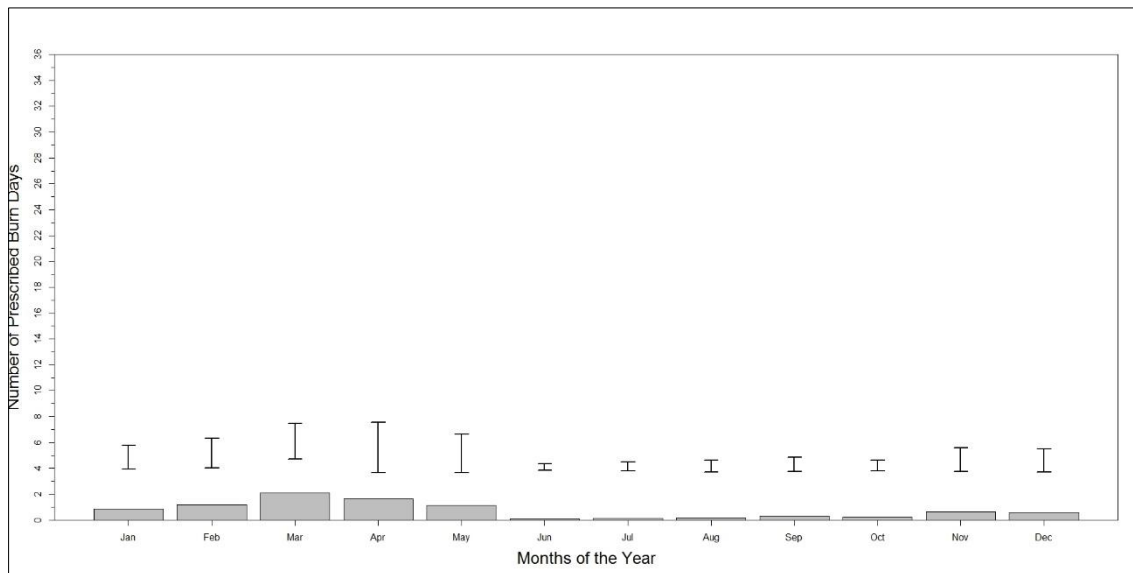


Figure 4.18 Average monthly number ( $\pm$ SD) of prescribed burn days in southern Florida from 1980-2010 with a mixing height threshold of  $\geq 1600$  m (using time 18z)

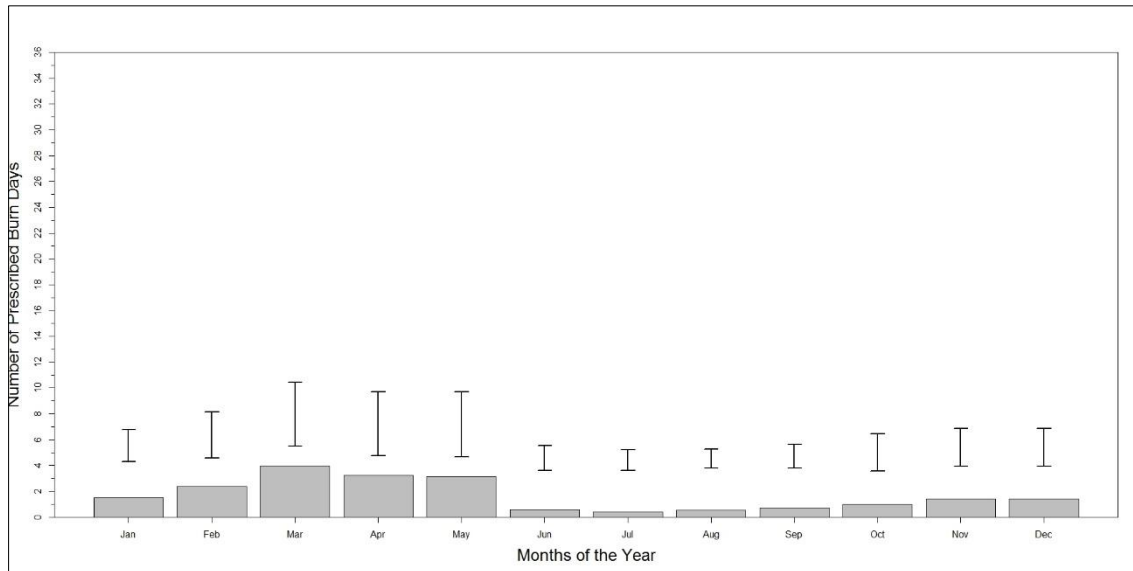


Figure 4.19 Average monthly number ( $\pm$ SD) of prescribed burn days in southern Florida from 1980-2010 with a mixing height threshold of  $\geq 1400$  m (using time 18z)

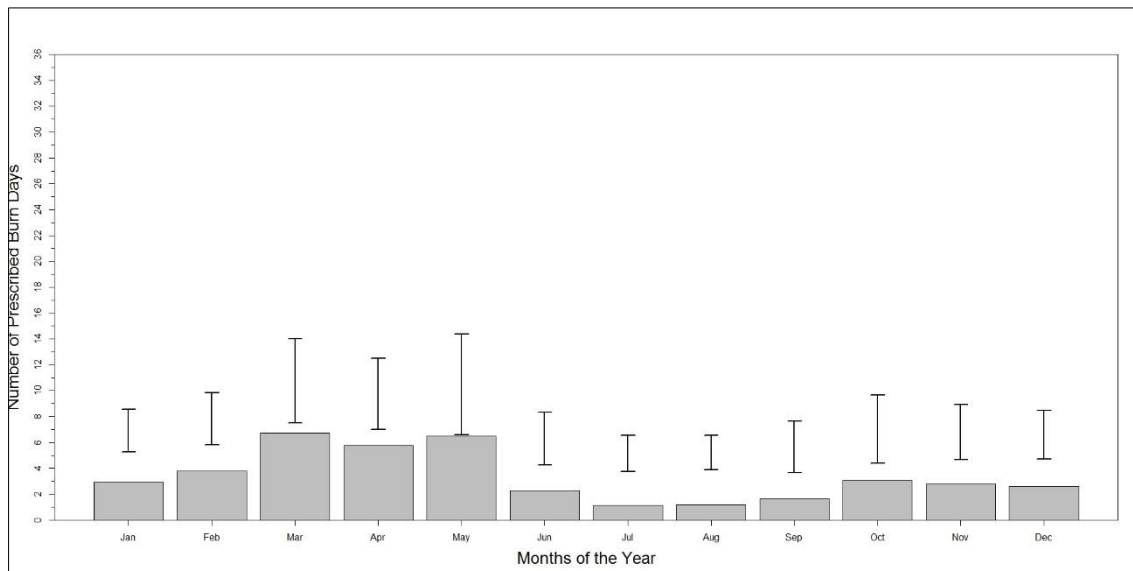


Figure 4.20 Average monthly number ( $\pm$ SD) of prescribed burn days in southern Florida from 1980-2010 with a mixing height threshold of  $\geq 1200$  m (using time 18z)

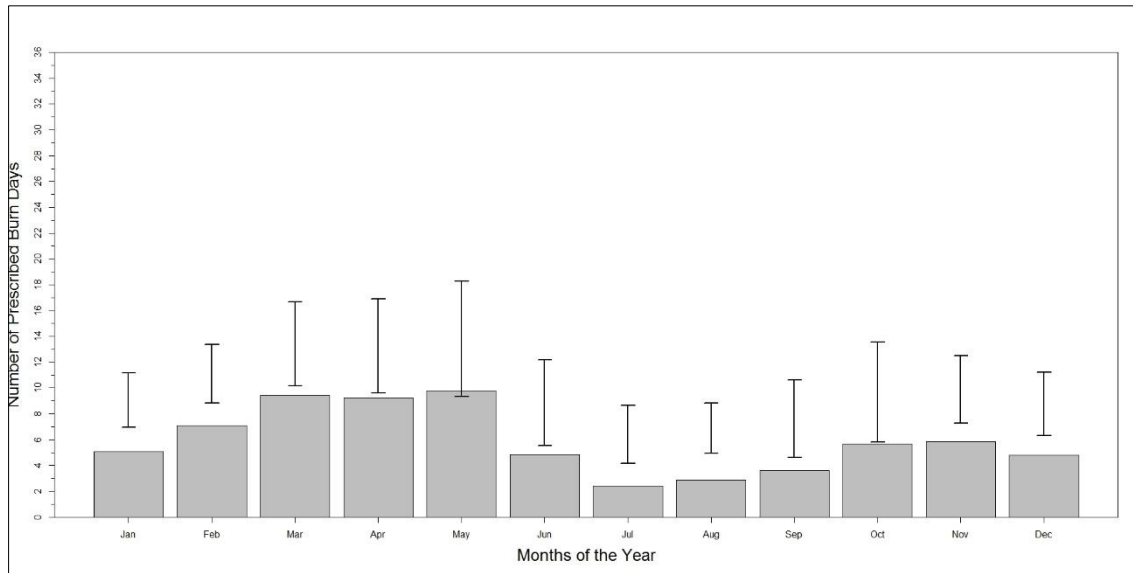


Figure 4.21 Average monthly number ( $\pm$ SD) of prescribed burn days in southern Florida from 1980-2010 with a mixing height threshold of  $\geq 1000$  m (using time 18z)

## CHAPTER V

### SOUTH CAROLINA RESULTS

#### 5.1 Overall

Prescribed burn days exhibited a contrast between northern, central and southern South Carolina. Annual prescribed burn days ranged from 0 to 350 days for the 30 year period (Figure 5.1). Looking at  $\geq 1800$  m mixing heights, average annual prescribed burn days ranged from 0 to 72 (Figure 5.2). Using  $\geq 1600$  m mixing heights, average annual prescribed burn days ranged from 9 to 86 (Figure 5.3). Looking at  $\geq 1400$  m mixing heights, average annual prescribed burn days ranged from 10 to 101 (Figure 5.4). Using  $\geq 1200$  m mixing heights, average annual prescribed burn days ranged from 26 to 107 (Figure 5.5). Looking at  $\geq 1000$  m mixing heights, average annual prescribed burn days ranged from 33 to 140 (Figure 5.6). Throughout all of these mixing heights, northern and southern South Carolina experienced relatively high number of days. However, central South Carolina experienced relatively low number of days.

#### 5.2 Seasonality

Each area of South Carolina experienced a difference in the amount of prescribed burn days based on time of year. For northern South Carolina the highest amount of prescribed burn days occurred from December through April. Prescribed burn days declined during from May through October in northern South Carolina (Figures 5.7–

5.11). While looking for mixing heights  $\geq 1600$  m, central South Carolina had the highest amount of prescribed burn days from April through June (Figures 5.12–5.16). Prescribed burn days were marginal during August through February in central South Carolina using mixing heights  $\geq 1600$  m. Prescribed burn days in central South Carolina had an extended season from December to July when using mixing heights  $\geq 1200$  m and  $\geq 1400$  m.

While looking for mixing heights  $\geq 1200$  m, southern South Carolina had the highest amount of prescribed burn days from April to June (Figures 5.17–5.21). Prescribed burn days were marginal during July through December in southern South Carolina using mixing heights  $\geq 1200$  m. Prescribed burn days in southern South Carolina were similar throughout the year when using mixing heights  $\geq 1000$  m.

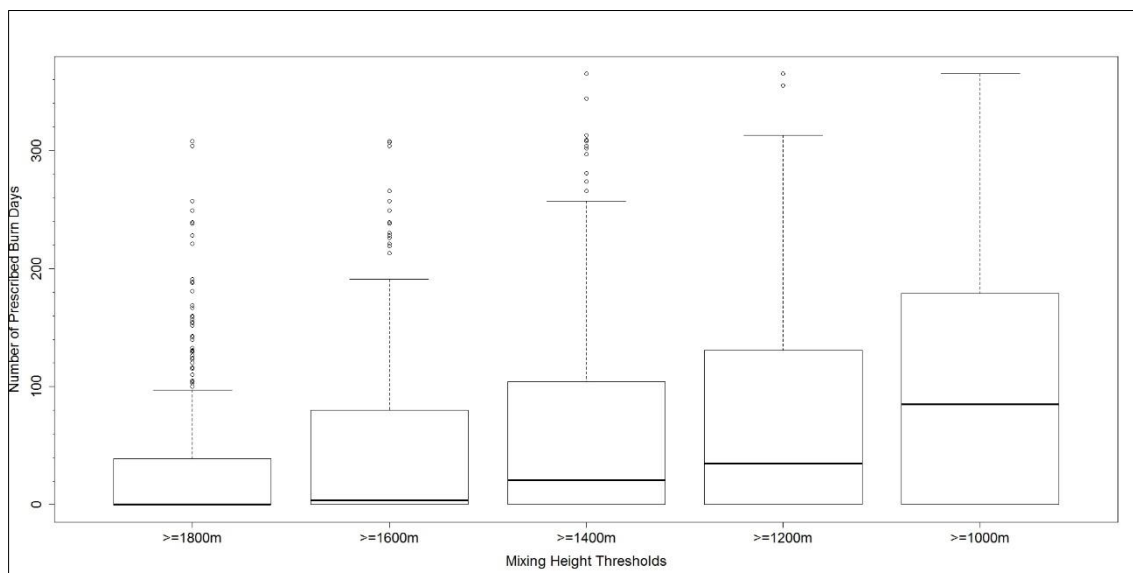


Figure 5.1 Box plots of annual prescribed burn days for South Carolina at 18z

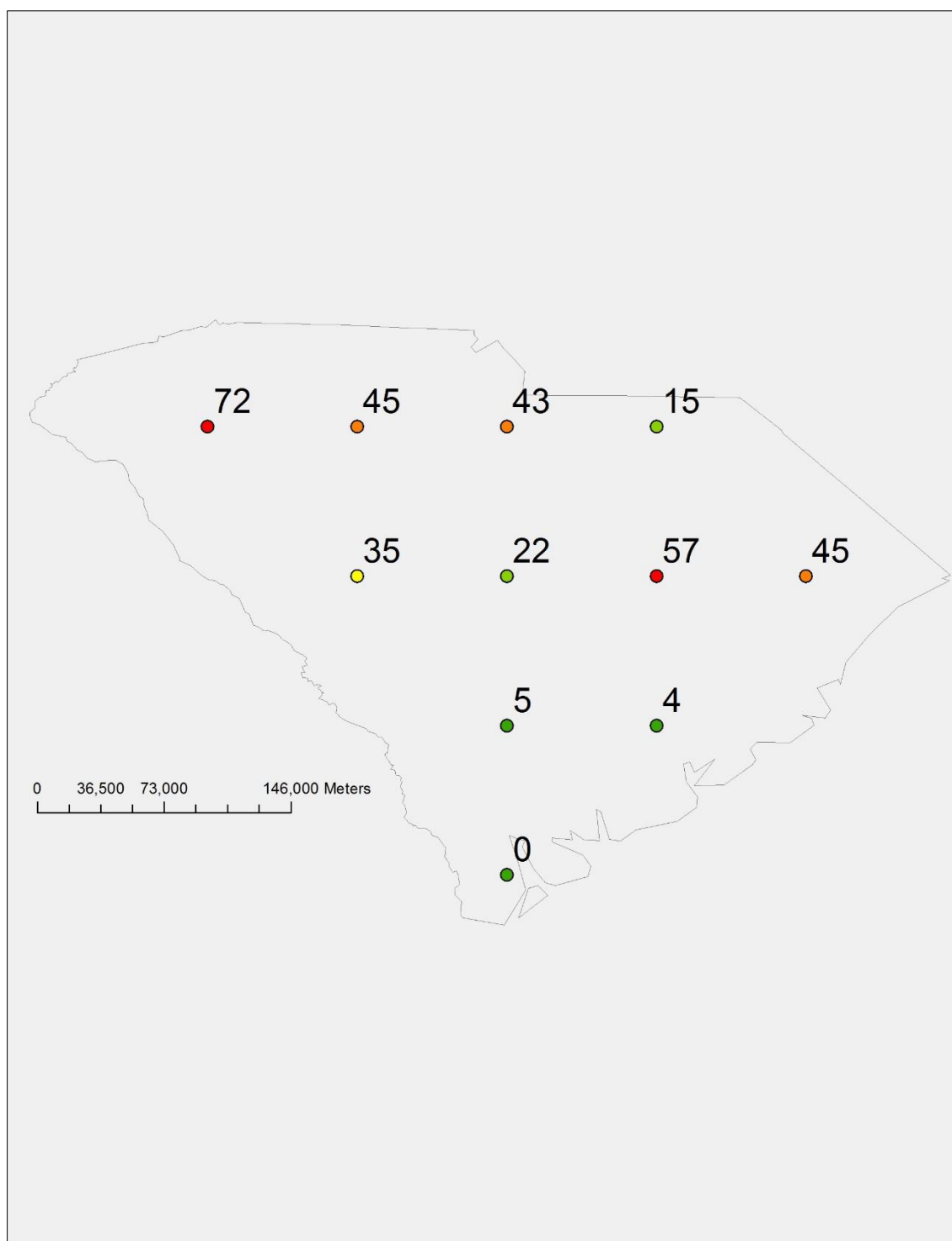


Figure 5.2 Map of the average annual prescribed burn days for South Carolina from 1980 to 2010 using mixing heights threshold of  $\geq 1800$  m

(using time 18z)

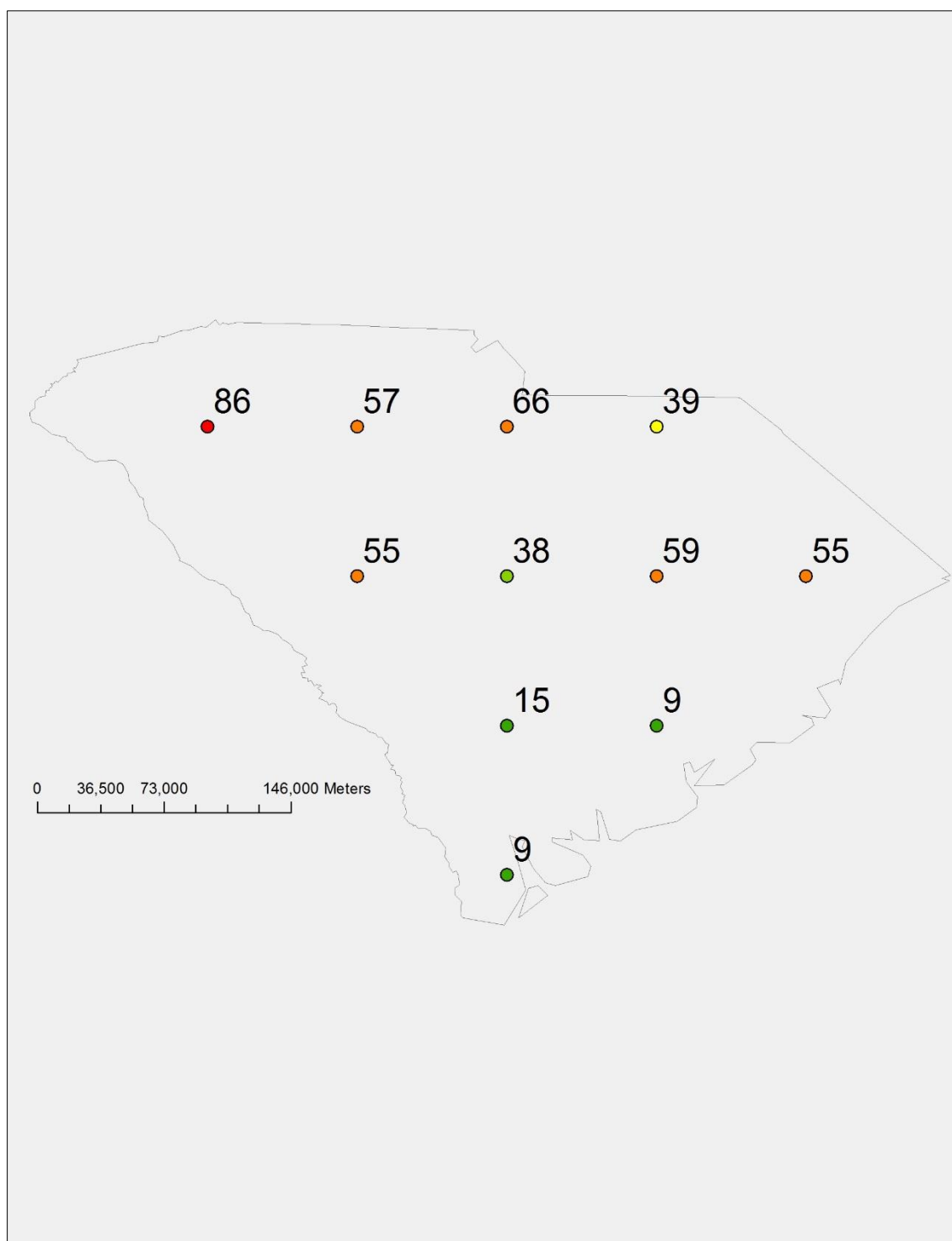


Figure 5.3 Map of the average annual prescribed burn days for South Carolina from 1980 to 2010 using mixing heights threshold of  $\geq 1600$  m

(using time 18z)

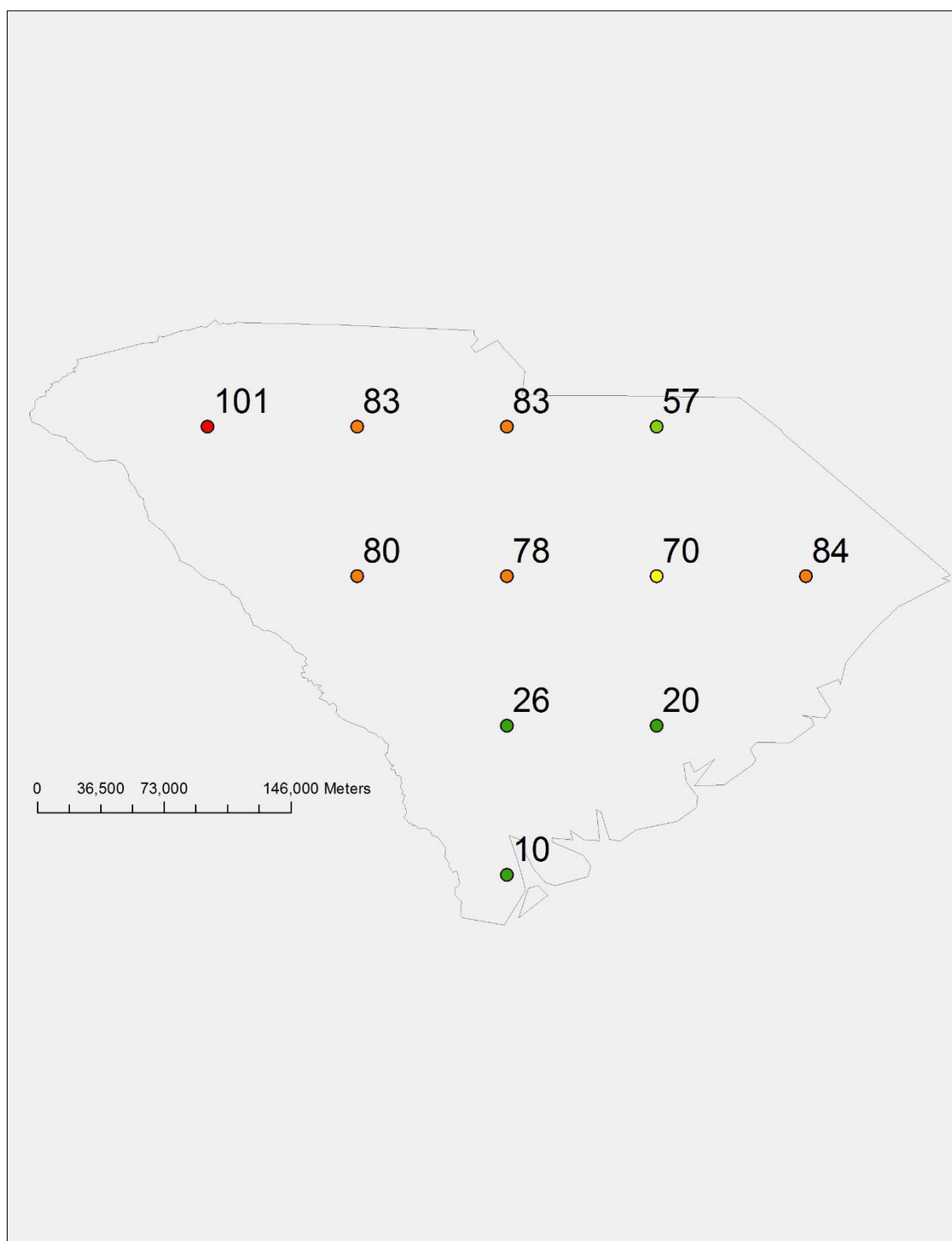


Figure 5.4 Map of the average annual prescribed burn days for South Carolina from 1980 to 2010 using mixing heights threshold of  $\geq 1400$  m

(using time 18z)



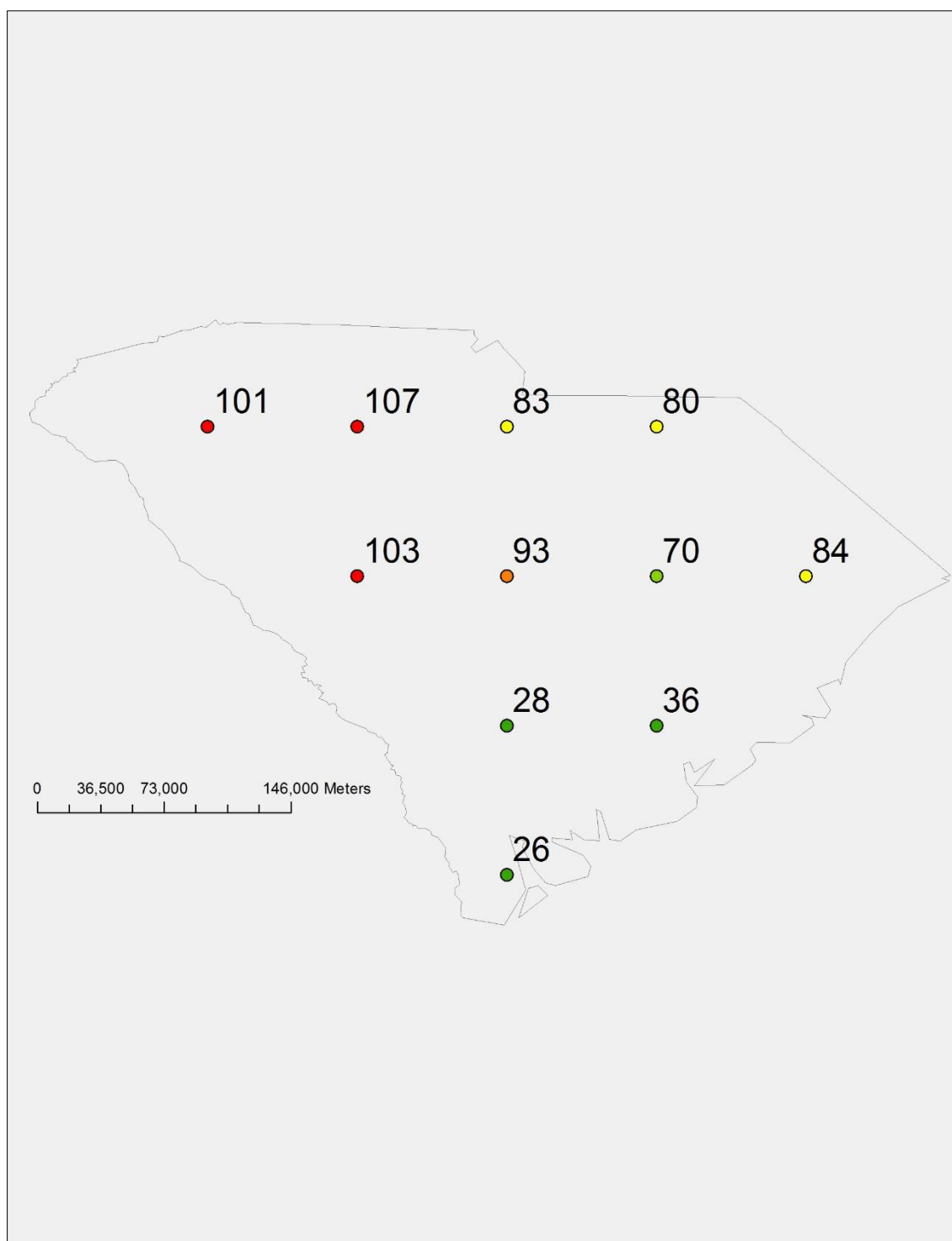


Figure 5.5 Map of the average annual prescribed burn days for South Carolina from 1980 to 2010 using mixing heights threshold of  $\geq 1200$  m

(using time 18z)

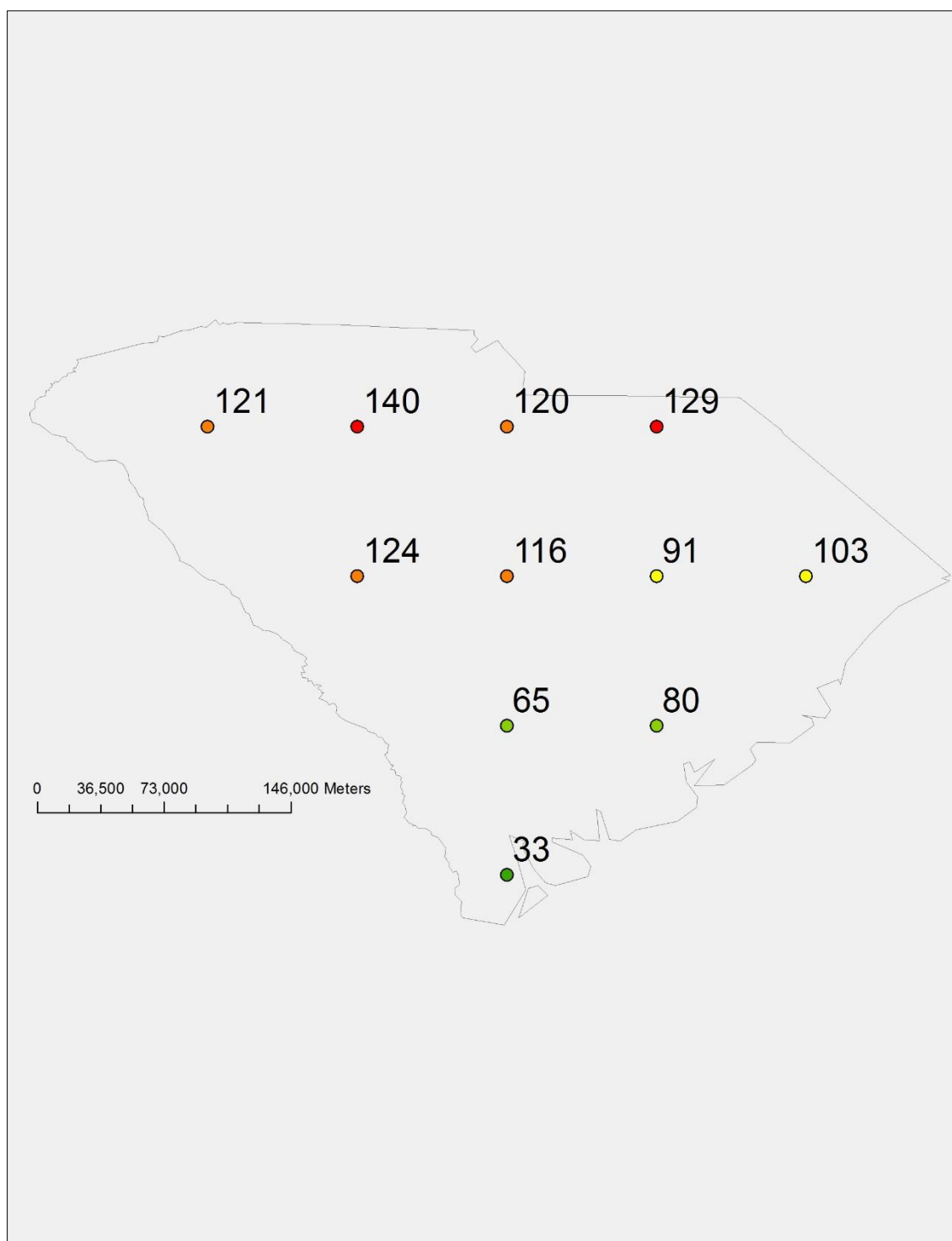


Figure 5.6 Map of the average annual prescribed burn days for South Carolina from 1980 to 2010 using mixing heights threshold of  $\geq 1000$  m

(using time 18z)

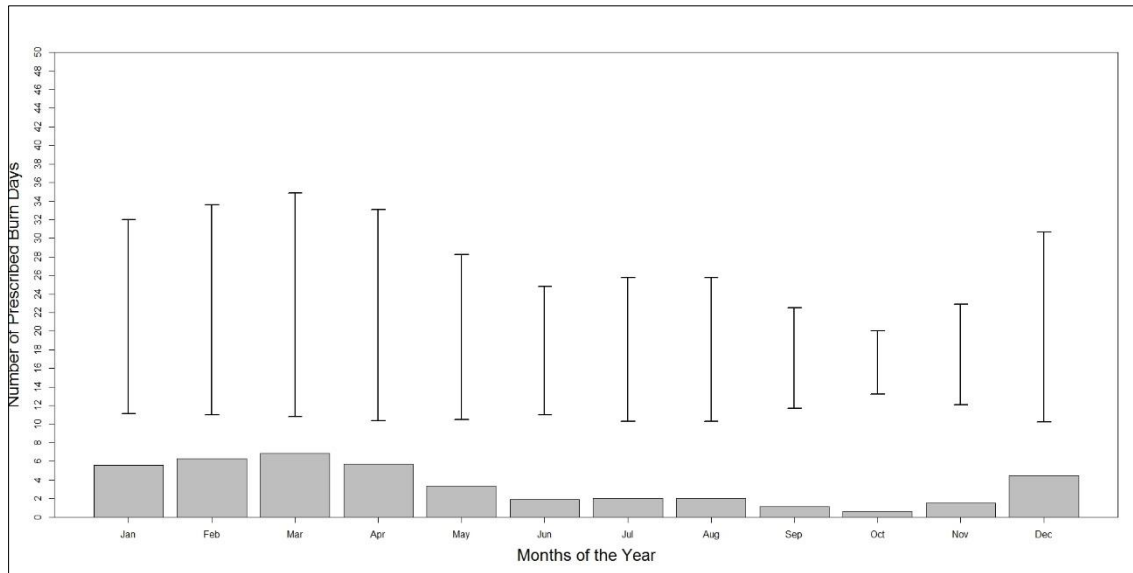


Figure 5.7 Average monthly number ( $\pm$ SD) of prescribed burn days in northern South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1800$  m (using time 18z)

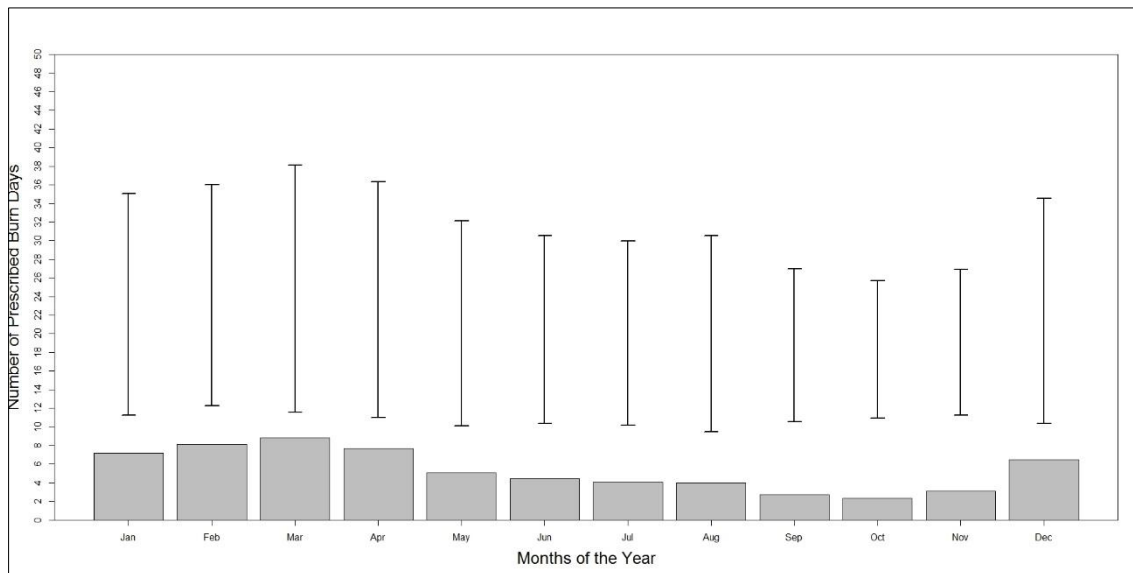


Figure 5.8 Average monthly number ( $\pm$ SD) of prescribed burn days in northern South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1600$  m (using time 18z)

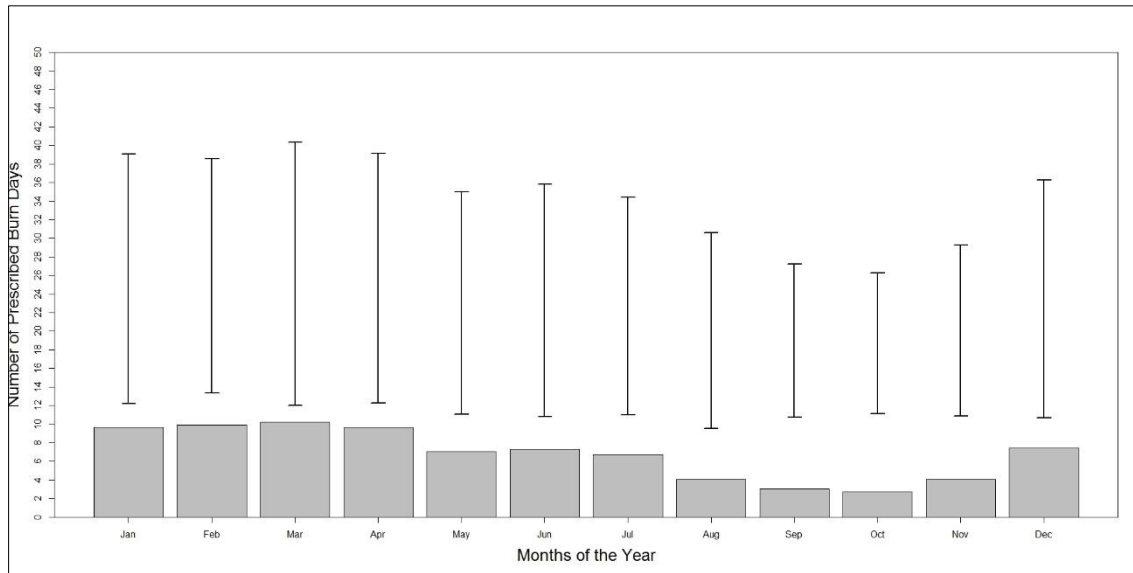


Figure 5.9 Average monthly number ( $\pm$ SD) of prescribed burn days in northern South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1400$  m (using time 18z)

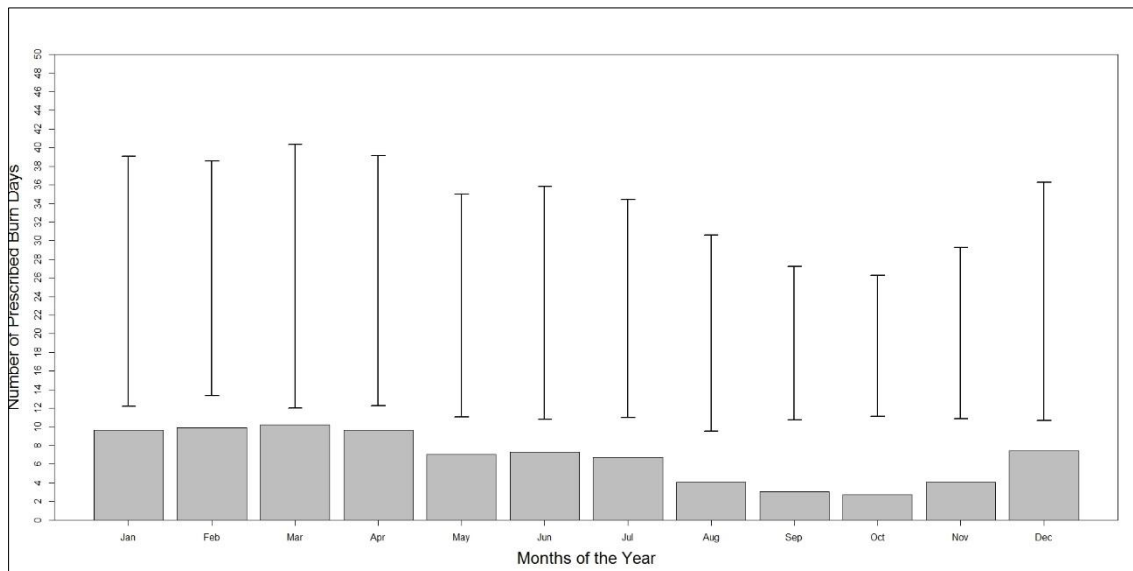


Figure 5.10 Average monthly number ( $\pm$ SD) of prescribed burn days in northern South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1200$  m (using time 18z)

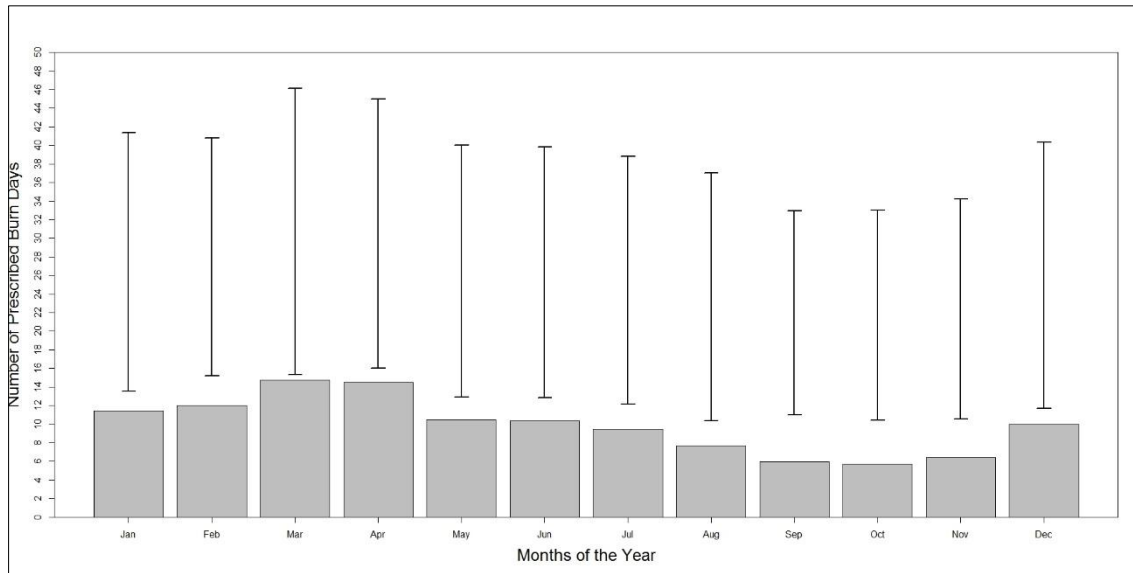


Figure 5.11 Average monthly number ( $\pm$ SD) of prescribed burn days in northern South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1000$  m (using time 18z)

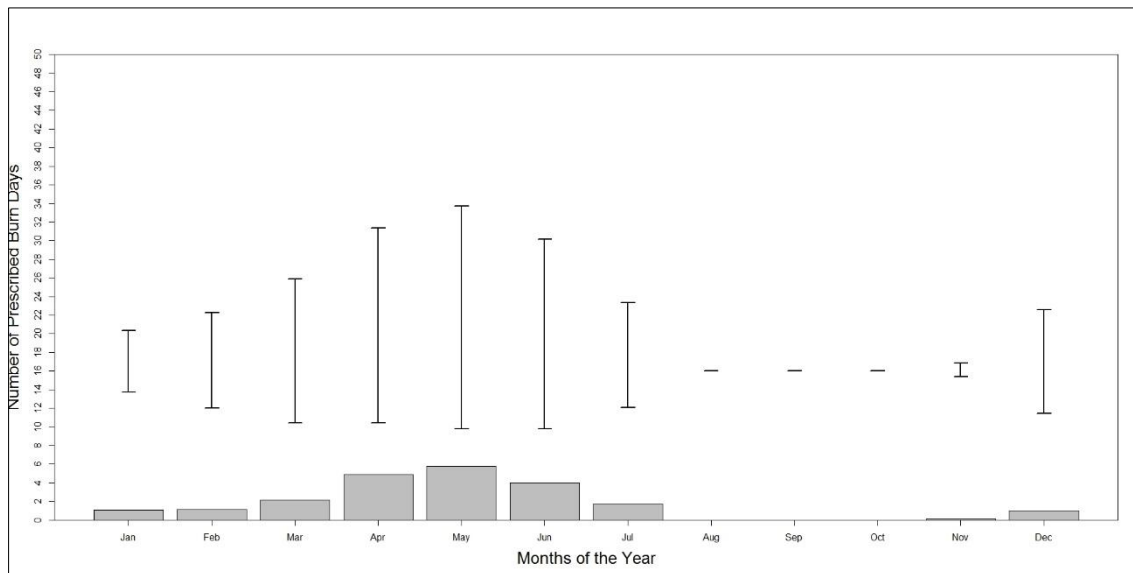


Figure 5.12 Average monthly number ( $\pm$ SD) of prescribed burn days in central South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1800$  m (using time 18z)

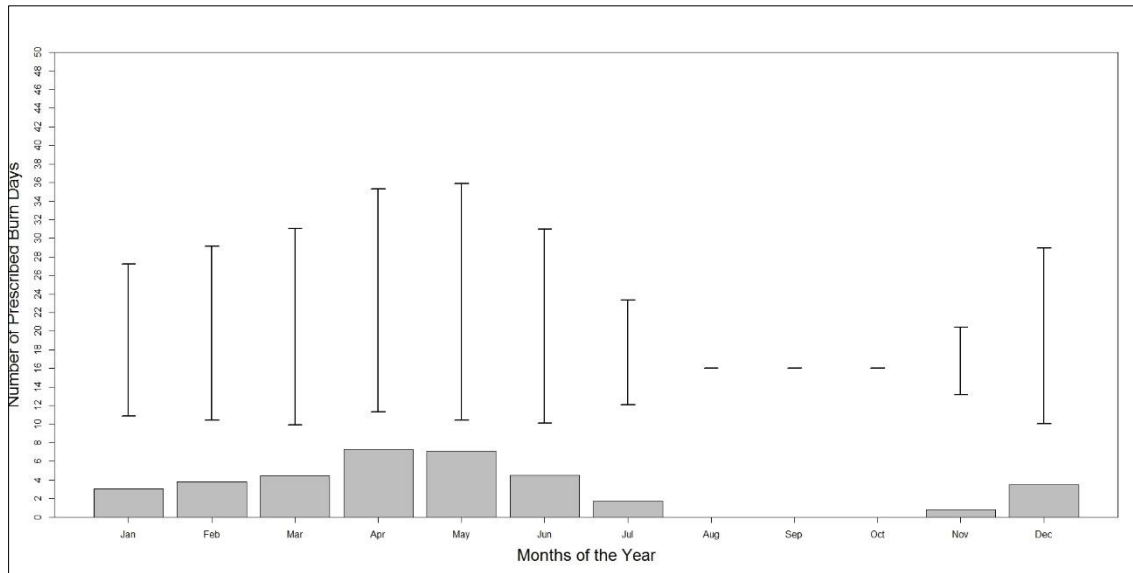


Figure 5.13 Average monthly number ( $\pm$ SD) of prescribed burn days in central South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1600$  m (using time 18z)

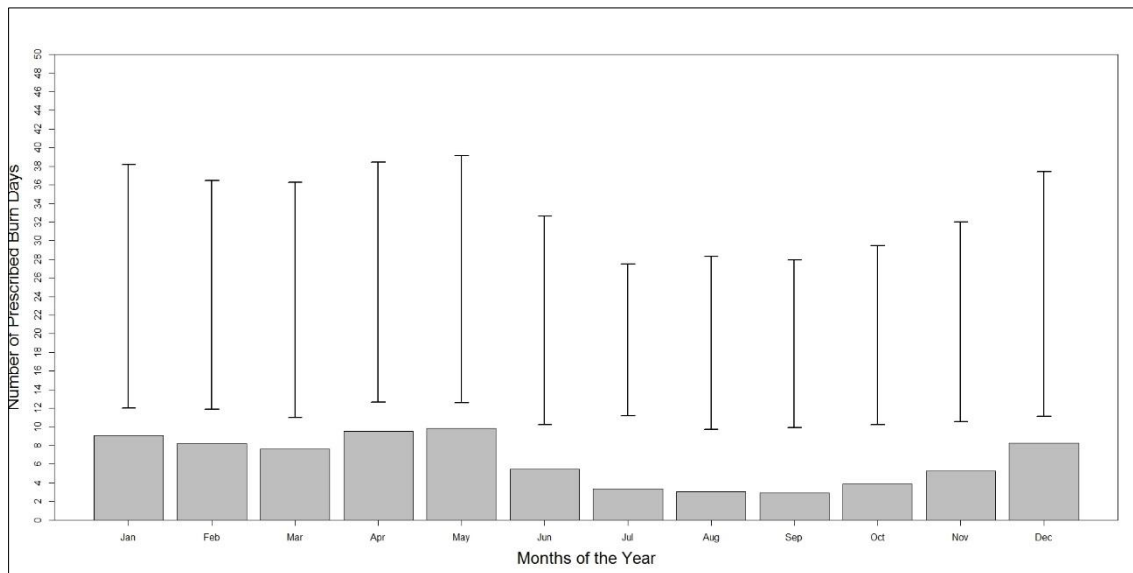


Figure 5.14 Average monthly number ( $\pm$ SD) of prescribed burn days in central South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1400$  m (using time 18z)

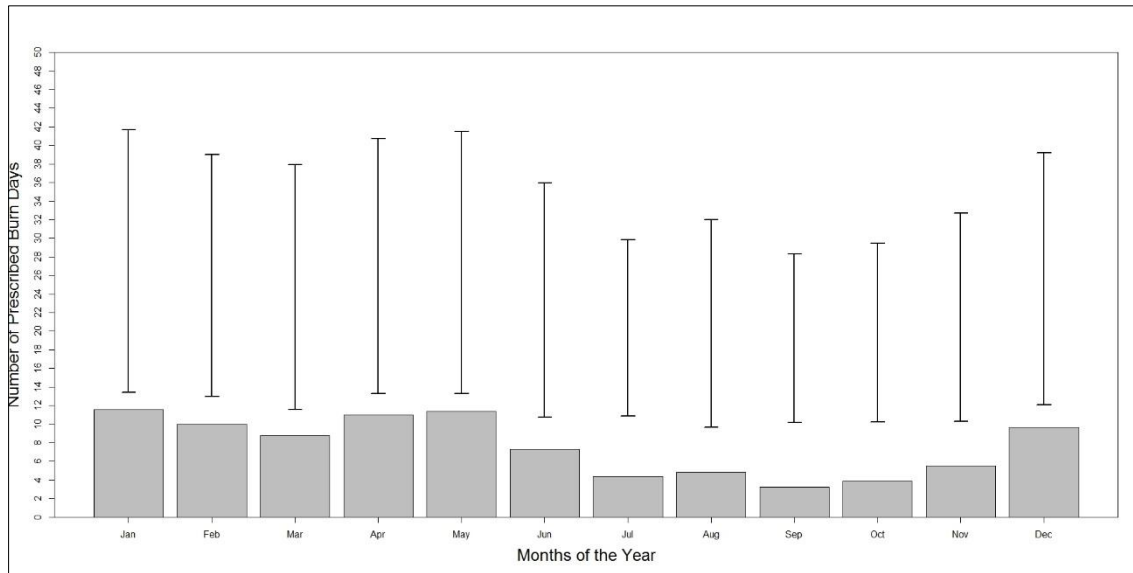


Figure 5.15 Average monthly number ( $\pm$ SD) of prescribed burn days in central South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1200$  m (using time 18z)

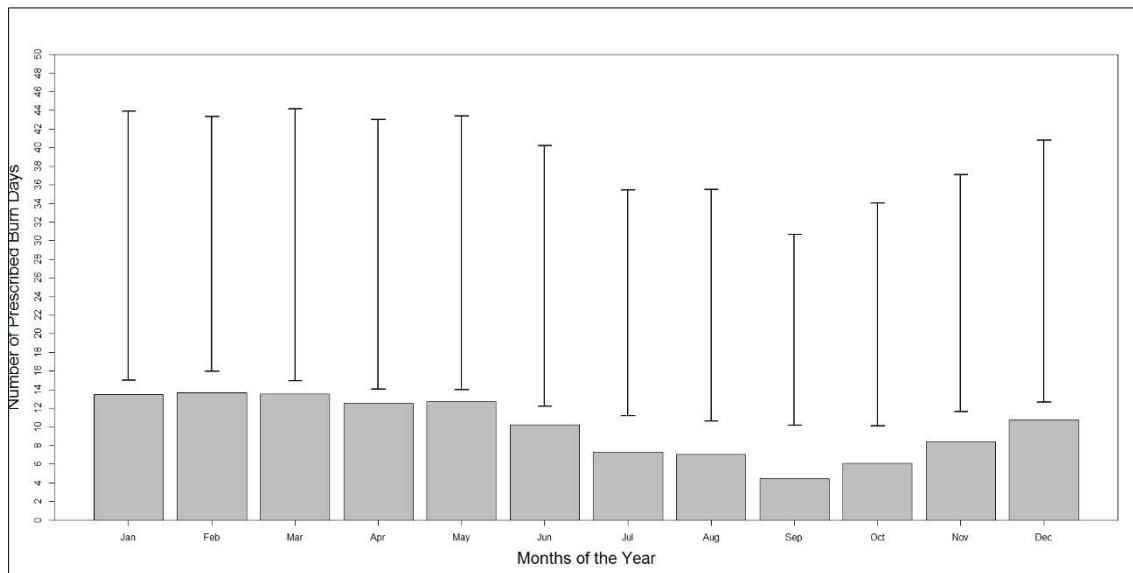


Figure 5.16 Average monthly number ( $\pm$ SD) of prescribed burn days in central South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1000$  m (using time 18z)

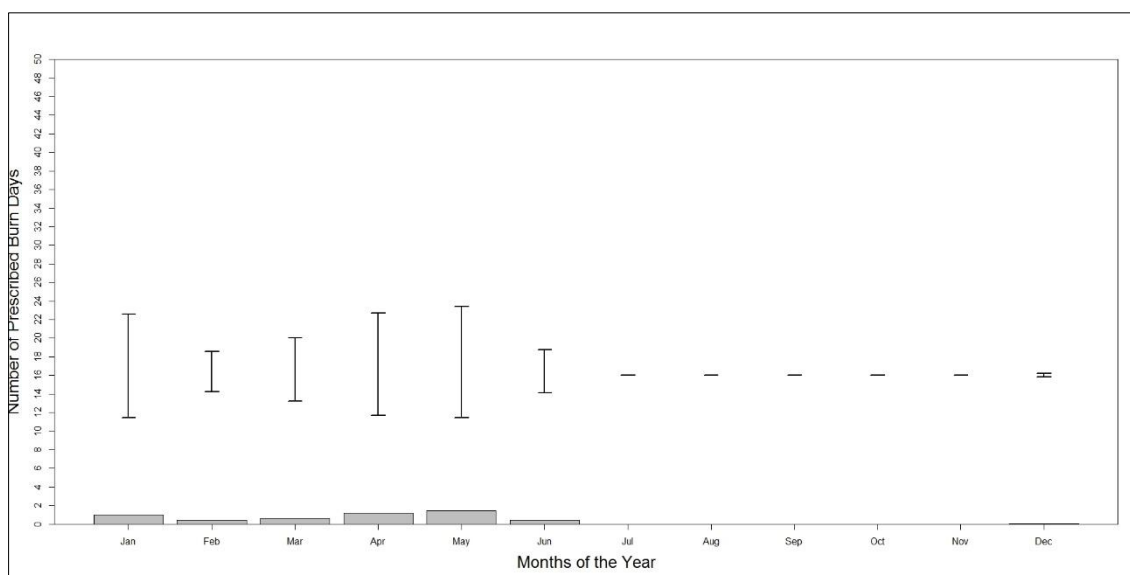


Figure 5.17 Average monthly number ( $\pm$ SD) of prescribed burn days in southern South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1800$  m (using time 18z)

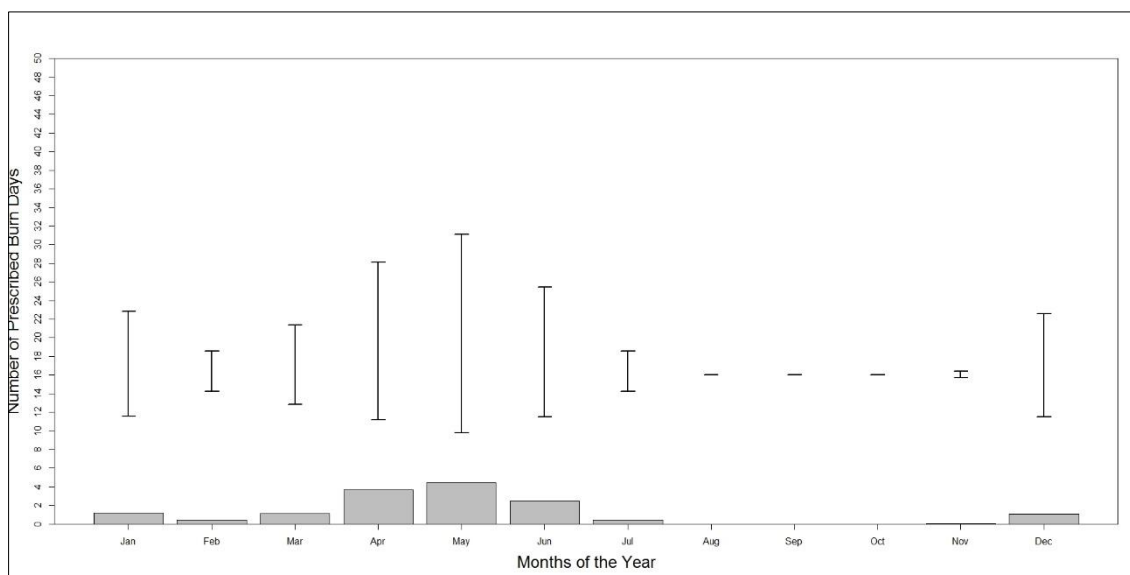


Figure 5.18 Average monthly number ( $\pm$ SD) of prescribed burn days in southern South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1600$  m (using time 18z)



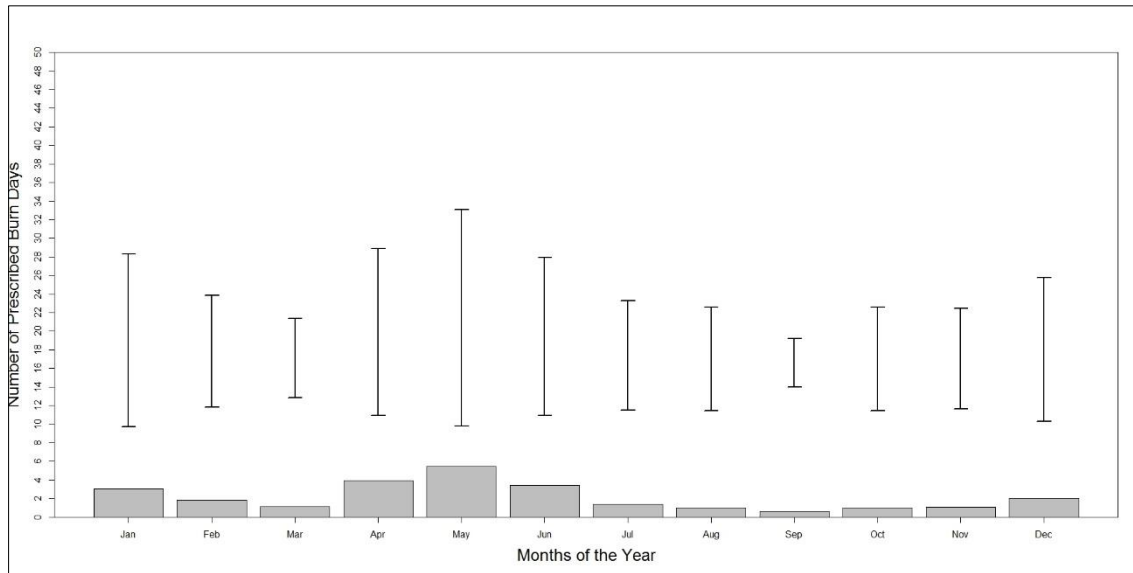


Figure 5.19 Average monthly number ( $\pm$ SD) of prescribed burn days in southern South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1400$  m (using time 18z)

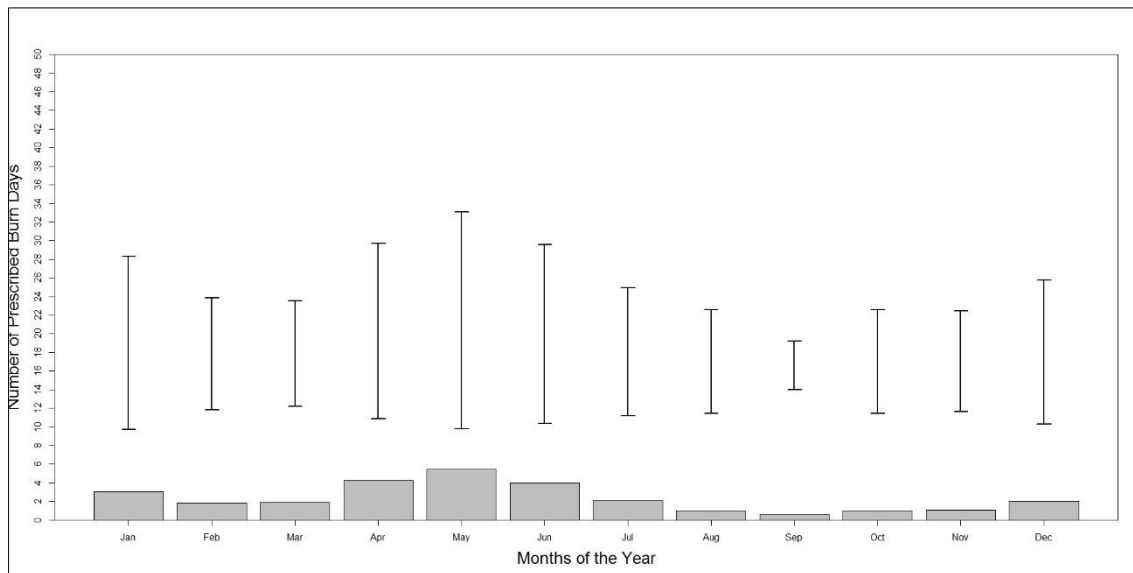


Figure 5.20 Average monthly number ( $\pm$ SD) of prescribed burn days in southern South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1200$  m (using time 18z)

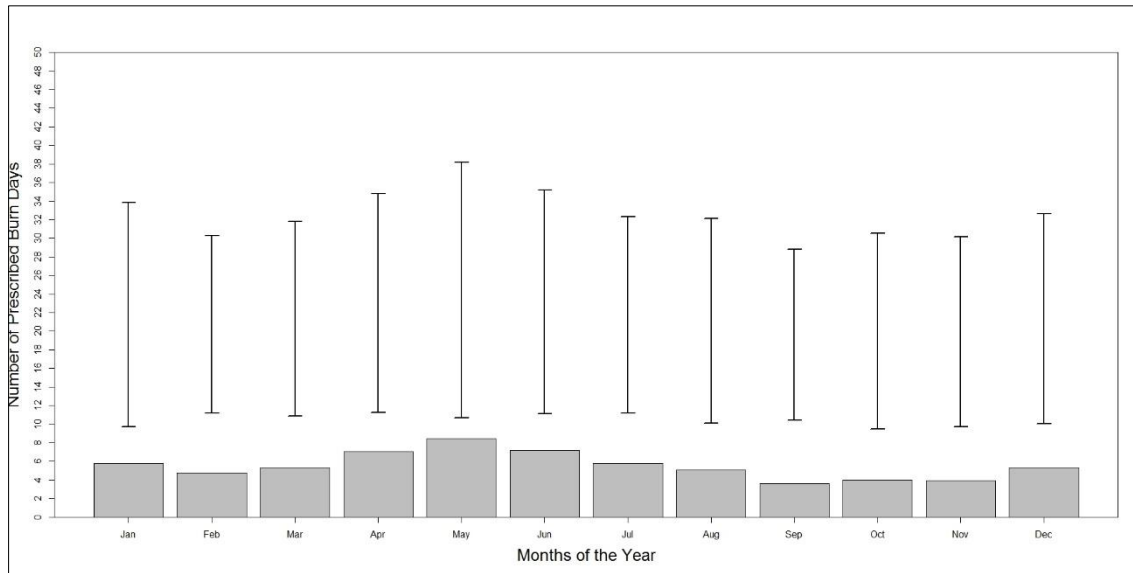


Figure 5.21 Average monthly number ( $\pm$ SD) of prescribed burn days in southern South Carolina from 1980-2010 with a mixing height threshold of  $\geq 1000$  m (using time 18z)

## CHAPTER VI

### CONCLUSIONS

Each state has its own weather criteria for a successful prescribed burn. However most of these restrictions are rather arbitrary. These restrictions limit the days prescribed burn managers can conduct a burn. To help improve this problem, I established a 30-year climatology. Results from all of the states selected for this research support the idea that a small decrease in mixing height can create a big increase in the annual number of prescribed burn days. Each state had seasonality of prescribed burn days. Also every state's prescribed burn days were different spatially. Overall Mississippi's season for prescribed burns was from December to April. The panhandle had the longest prescribed season in Florida. Central Florida had the shortest prescribed season in Florida. Based on South Carolina's findings, states that have higher-than-average prescribed burn days have relatively small increases of prescribed burn days. The number of prescribed burn days for each state overall aligned with statistics from the National Interagency Fire Center where Mississippi had the lowest burn days and South Carolina had the highest burn days. Hopefully this research will help policy makers reduce the criteria needed for prescribed burns. This will reduce the cost, increase the effectiveness, and maximize the benefits of prescribed burns.

## CHAPTER VII

### LIMITATIONS/FUTURE RESEARCH

This research can be expanded to incorporate several other regions in the United States. Future research will need to be done for the entire Southeast. This would create a more optimal view of how prescribed burn days in one state differ from other states. However, there are several limitations to the areas that can be studied. The first limitation is that studies could not be conducted in areas of mountainous terrain because mixing heights are difficult to predict with accuracy. This is due to having multiple inversions happen at multiple times of the day in mountainous terrain. The second limitation is that studies must be conducted in areas with similar vegetation. This has to be done because vegetation has different fire-resistant and/or moisture-related properties. Similarly, current policies have different criteria for different vegetation.

## REFERENCES

- Achtemeier, G.L.; Liu, Y. 2009. Smoke transport and dispersion from prescribed burns: complications posed by mountainous terrain. 24th Tall Timbers Fire Ecology Conference, Tallahassee, FL, January 12-15, 2009. (poster)
- Anderson, E.B., & R.S. Hales, (1986). Critical Path Method applied to research project planning: Fire economics evaluation systems(FEES). USDA
- Arya, S. P. S. (1981). Parameterizing the height of the stable atmospheric boundary layer. *Journal of Applied Meteorology*, 20(10), 1192-1202.
- Botelho, H. S., Fernandes, P.M., & Loureiro, C.(1999). Fire hazard implications of alternative fuel management techniques—case studies from northern Portugal. In *Proceedings from The Joint Fire Science Conference and Workshop, Idaho*.
- Brender, Ernst V., & Cooper, Robert W. (1968). Prescribed burning in Georgia's Piedmont loblolly pine stands. *Journal of Forestry*, 66(1), 31-36.
- Cramer, Owen P. (1957). Forest fire weather in western Oregon and western Washington in 1957. PNW Old Series Research Notes No. 154: 19 p
- Goodrick, S., & Waldrop, T. (2012). Introduction to Prescribed Fire in Southern Ecosystems (pg. 1-33). Asheville,NC: Forest Service Southern Research Station.
- Green, L. R. (1981). Burning by prescription in chaparral. Berkeley (CA): USDA Forest Service, Pacific Southwest Forest and Range Experiment Station. Gen Tech Report PSW-51.
- Haines, T. K., Busby, R. L., & Cleaves, D. A. (2001). Prescribed burning in the South: trends, purpose, and barriers. *Southern Journal of Applied Forestry*, 25(4), 149-153
- Hesseln, H. (2000). The economics of prescribed burning: a research review. *Forest Science*, 46(3), 322-334.
- Holzworth, G. C. (1967). Mixing depths, wind speeds and air pollution potential for selected locations in the United States. *Journal of applied Meteorology*, 6(6), 1039-1044.

- Lunsford, J. D. et al. (1989). A guide for prescribed fire in southern forests. Technical Publication R8-TP-US Department of Agriculture, Forest Service, Southern Region.
- Martin RE, Landsberg JD, Kauffman JB (1988) Effectiveness of prescribed burning as a fire prevention measure. In 'Proceedings of the international workshop on prescribed burning'. pg. 31–44.
- National Interagency Fire Center. (2008). Historical Year-end Fire Statistics by State (source NICC).
- Outcalt, Kenneth W.; Wade, Dale D. 2000. The value of fuel management in reducing wildfire damage. In: Neuenschwander, Leon F.; Ryan, Kevin C., tech. eds. Proceedings from the Joint Fire Science Conference and Workshop: crossing the millennium: integrating spatial technologies and ecological principles for a new age in fire management; the Grove Hotel, Boise, Idaho, June 15-17, 1999. Moscow, Idaho: University of Idaho, 2000: 271-275.
- Rego FC (1991) Fuel management. In 'ECE/FAO/ILO seminar on forest fire prevention, land use and people'. pg. 209–221. (Ministry of Agriculture: Athens, Greece)
- Roberts, K. W., Engle, D. M., & Weir, J. R. (2006). Weather constraints to scheduling prescribed burns. *Rangelands Archives*, 21(6), 6-7.
- Runyen, J. (2007). Guide to South Texas Fire Weather. Corpus Christi, Tx: Fire Weather Program.
- Ryan, K. C., Knapp, E. E., & Varner, J. M. (2013). Prescribed fire in North American forests and woodlands: history, current practice, and challenges. *Frontiers in Ecology and the Environment*, 11(s1), e15-e24.
- US Environmental Protection Agency. (2008). AERSURFACE User's Guide.
- Vega JA, et al. (1994) Forest fire prevention through prescribed burning: an international cooperative project carried out in the European STEP program. In 'Proceedings of the 2nd international conference on forest fire research'. pg. 75–84
- Wier, John R. (2004). Probability of spot fires during prescribed burns. *Fire Management Today*, 64(2), 24-26.
- Wood, D. B. (1988). Costs of prescribed burning in southwestern ponderosa pine. *Western Journal of Applied Forestry*, 3(4), 115-119.

APPENDIX A  
R PROGRAMMING SCRIPT

```

mh1.num<-matrix(scan("80mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh1.num
mh2.num<-matrix(scan("81mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh2.num
mh3.num<-matrix(scan("82mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh3.num
mh4.num<-matrix(scan("83mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh4.num
mh5.num<-matrix(scan("84mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh5.num
mh6.num<-matrix(scan("85mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh6.num
mh7.num<-matrix(scan("86mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh7.num
mh8.num<-matrix(scan("87mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh8.num
mh9.num<-matrix(scan("88mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh9.num
mh10.num<-matrix(scan("89mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh10.num
mh11.num<-matrix(scan("90mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh11.num
mh12.num<-matrix(scan("91mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh12.num
mh13.num<-matrix(scan("92mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh13.num
mh14.num<-matrix(scan("93mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh14.num
mh15.num<-matrix(scan("94mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh15.num
mh16.num<-matrix(scan("95mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh16.num
mh17.num<-matrix(scan("96mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh17.num
mh18.num<-matrix(scan("97mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh18.num
mh19.num<-matrix(scan("98mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh19.num
mh20.num<-matrix(scan("99mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh20.num
mh21.num<-matrix(scan("00mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh21.num
mh22.num<-matrix(scan("01mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh22.num
mh23.num<-matrix(scan("02mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh23.num
mh24.num<-matrix(scan("03mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh24.num
mh25.num<-matrix(scan("04mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh25.num
mh26.num<-matrix(scan("05mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh26.num
mh27.num<-matrix(scan("06mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh27.num
mh28.num<-matrix(scan("07mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh28.num
mh29.num<-matrix(scan("08mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh29.num
mh30.num<-matrix(scan("09mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#

```



```

mh20.num
mh21.num<-matrix(scan("00mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh21.num
mh22.num<-matrix(scan("01mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh22.num
mh23.num<-matrix(scan("02mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh23.num
mh24.num<-matrix(scan("03mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh24.num
mh25.num<-matrix(scan("04mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh25.num
mh26.num<-matrix(scan("05mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh26.num
mh27.num<-matrix(scan("06mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh27.num
mh28.num<-matrix(scan("07mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh28.num
mh29.num<-matrix(scan("08mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh29.num
mh30.num<-matrix(scan("09mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh30.num
mh31.num<-matrix(scan("10mh2048.txt"),ncol=1,byrow=T) #scan in 2048 mixing height values#
mh31.num

mh33=append(mh1.num,mh2.num)
mh34=append(mh33,mh3.num)
mh35=append(mh34,mh4.num)
mh36=append(mh35,mh5.num)
mh37=append(mh36,mh6.num)
mh38=append(mh37,mh7.num)
mh39=append(mh38,mh8.num)
mh40=append(mh39,mh9.num)
mh41=append(mh40,mh10.num)
mh42=append(mh41,mh11.num)
mh43=append(mh42,mh12.num)
mh44=append(mh43,mh13.num)
mh45=append(mh44,mh14.num)
mh46=append(mh45,mh15.num)
mh47=append(mh46,mh16.num)
mh48=append(mh47,mh17.num)
mh49=append(mh48,mh18.num)
mh50=append(mh49,mh19.num)
mh51=append(mh50,mh20.num)
mh52=append(mh51,mh21.num)
mh53=append(mh52,mh22.num)
mh54=append(mh53,mh23.num)
mh55=append(mh54,mh24.num)
mh56=append(mh55,mh25.num)
mh57=append(mh56,mh26.num)
mh58=append(mh57,mh27.num)
mh59=append(mh58,mh28.num)
mh60=append(mh59,mh29.num)
mh61=append(mh60,mh30.num)
mh62=append(mh61,mh31.num)
write(mh62,file="mh18z_2048.txt",ncol=1,sep="\t")
mh63<-matrix(scan("mh18z_2048.txt"),ncol=1,byrow=T)
hist(mh63[,1],xlab="Mixing Heights (m)",ylab="Frequency",xlim=c(0,10000),ylim=c(0,5000),main=
z=quantile(mh63,0.95)
abline(v=z,col="red")

```

```
mhms1.file<-matrix(scan("80mh2130.txt"),ncol=1,byrow=T) #scan in mixing heights
mhms.file
year="1980"
x=mhms1.file[,1]
#The following is the amount of prescribed burn days based on mixing height thresholds
a=sum(ifelse(x>=1800,1,0))
b=sum(ifelse(x>=1600,1,0))
c=sum(ifelse(x>=1400,1,0))
d=sum(ifelse(x>=1200,1,0))
e=sum(ifelse(x>=1000,1,0))
```

## APPENDIX B

### PYTHON SCRIPTS: PROCESS THE DATA INTO U AND V COMPONENT VALUES

```

#This program is used to convert the original data into useful data that can be implemented into gis
yearf="2010"#user defined year
year="10"#user defined year
var="u"#user defined variable u is u component of wind v is v component of wind
lyear="N"#is the year a leap year Y or N
d=1#initial day
h=0*366#user defined layer number
z=h
e=1
w="2010"#user defined year
varu="var0"#if variable is u use this for file management
varv="var1"#if variable is v use this for file management
start="wnd10mx0.5.gdas."#data start with this for u and v components
import arcpy#import arcpy
-def ras(x,y,z):#converts ascii files to rasters
    import arcpy #need arcpy module stored in python browser path
    # x is the import ascii file. Must put extension e.g. .asc
    #y is the output raster file.
    #input workspace
    c=arcpy.env.workspace="B:\\CFSR\\ascii\\"+w+"\\v\\18z\\Day"+z#workspace changes based upon user input
    d=arcpy.env.workspace="B:\\CFSR\\rasters\\"+w+"\\v\\18z\\Day"+z#workspace changes based upon user input
    arcpy.ASCIIToRaster_conversion(str(c+"\\")+x,str(d+"\\")+y,"INTEGER")#runs the ASCII to Raster Conversion tool
-def aggr(x,y,z):#aggregate the raster file to reduce available points needed for analysis on each state
    import arcpy
    from arcpy import env
    from arcpy.sa import *
    try:
        if arcpy.CheckExtension("Spatial") == "Available":
            arcpy.CheckOutExtension("Spatial")
            w="2010"
            yearf="2010"
            year="10"
            var="v"
            lyear="N"
            env.workspace="B:\\CFSR\\rasters\\"+w+"\\v\\18z\\Day"+z
            outAggreg=Aggregate(str(x), 10, "MAXIMUM")#reduce raster size by a factor of ten using maximum values
            outAggreg.save(str(y))
        else:
            # Raise a custom exception
            #
            raise LicenseError
    finally:
        # Check in the ArcGIS 3D Analyst extension
        #
        arcpy.CheckInExtension("Spatial")
-def point(x,y,z):#convert aggregated rasters to points
    import arcpy #need arcpy module stored in python browser path
    w="2010"
    d=arcpy.env.workspace="B:\\CFSR\\rasters\\"+w+"\\v\\18z\\Day"+z #workspace changes based upon user input
    e=arcpy.env.workspace="B:\\CFSR\\shapefiles\\"+w+"\\v\\18z\\Day"+z #workspace changes based upon user input
    arcpy.RasterToPoint_conversion(str(d+"\\")+x,str(e+"\\")+y)#runs the Raster to Point Conversion tool
    yearf="2010"
    year="10"
    var="v"

```

```

location=2448,2449,2450,2527,2528,2529,2530,2607,2608,2609,2610,2687,2688,2689,2690,2767,2768,2769,2770,2849,2850#user defined location points
string=str(location[g])#convert location into string
length=len(location)#assign variable to length of location
y=string
x=string
rows=[]#create an empty list
i=1
z=1
a=arcpy.env.workspace="B:\\CFSR\\shapefiles\\"+w+"\\u\\18z\\Day"+str(d)#define the input workspace
b=arcpy.env.workspace="B:\\CFSR\\shapefiles\\"+w+"\\u\\"+x+"\\18z\\Day"+str(d)#define the output workspace
lyrFile="lyr"+str(z)#define layer number
arcpy.MakeFeatureLayer_management(str(a+"\\a18z01"+var+year+"01.shp"),lyrFile)#Make a layer
rh=arcpy.SelectLayerByAttribute_management(lyrFile,"NEW_SELECTION","\\POINTID\\='"+x+"'")#select the location out of the whole united states
arcpy.management.CopyFeatures(rh,str(b+"\\18z_"+var+"_"+year+"_01_"+y))#copy the selection to a new shapefile
z=z+1#add one to the layer number
def dbf2csv(x):#Convert the dbfs of shapefiles to csv
    counter=0
    e=1
    while counter<31:#Do this for all 31 days
        import csv#import csv module
        from dbfpy import dbf#import dbfpy module
        import os#import os
        path="B:/CFSR/shapefiles/"+str(w)+"/u/"+str(j)+"/18z/Day"+str(e)#path of files
        for dirpath, dirnames, filenames in os.walk(path):
            for filename in filenames:
                os.chdir(path)#change directory to path
                if filename.endswith('.dbf'):#find all files that have dbfs
                    csv_fn=os.path.join(dirpath,filename)
                    csv_fn = csv_fn[:-4]+ ".csv"#remove dbf extension and add csv extension
                    with open(csv_fn,'wb') as csvfile:#open file as a writeable file
                        in_db = dbf.Dbf(os.path.join(dirpath, filename))
                        out_csv=csv.writer(open(csv_fn,'wb'))#extract values
                        names=[]#create an empty list
                        for field in in_db.header.fields:
                            names.append(field.name)#append the name to the file
                        out_csv.writerow(names)#write the values of dbf file to new file
                        for rec in in_db:
                            out_csv.writerow(rec.fieldData)
                        in_db.close()#close file
                e=e+1
            counter=counter+1#go to next day
def u(f,b):#change to which variable you need
    import os
    import glob
    #a is the where the shapefiles are located for a certain city e.g. JacksonMS
    #d is the empty textfile that you have created
    x=0
    point=str(string)#convert to string and assign to variable
    value=0
    d=year+"u"+point+".txt"#text file name to extract values to
    var="u"
    lyer="y"
    os.chdir("B:\\CFSR\\shapefiles\\"+w+"\\u\\"+point+"\\18z\\Day"+str(f))#change directory for input
    # set initial value for position of the itemized list of csv files associated in y

```

```

        e=e+1
        counter=counter+1#go to next day
def u(f,b):#change to which variable you need
    import os
    import glob
    #s is the where the shapefiles are located for a certain city e.g. JacksonMS
    #d is the empty textfile that you have created
    x=0
    point=str(string)#convert to string and assign to variable
    value=0
    d=year+"u"+point+".txt"#text file name to extract values to
    var="u"
    lyear="y"
    os.chdir("B:\\CFSR\\shapefiles\\"+w+"\\u\\"+point+"\\18z\\Day"+str(f))#change directory for input
    # set initial value for position of the itemized list of csv files associated in y
    y=glob.glob('*.csv')#find all files that end with csv
    z=y[b] # z equals the item in the position in the itemized list in y
    x=str(z) #x is the conversion of z into a string
    data=open("B:\\CFSR\\shapefiles\\"+w+"\\u\\"+point+"\\18z\\Day"+str(f)+"\\x").read()#open the new created file
    row=data.replace("\n","") #take out new lines and replace it with nothing
    if len(row)==24: #if the length is 24 then add the 22nd and 23rd position because the value will be two digits
        value=str(row[22]+row[23])
    elif len(row)==25: #if the length is 25 then add the 22nd, 23rd, and 24th position because the value will be three digits
        value=str(row[22]+row[23]+row[24])
    elif len(row)==23: #if the length is 23 then add 22nd position because the value will be one digit
        value=str(row[22])
    rows.append(value)
#This script is used to convert text files to csv files
import csv
import glob
import os
m=0
counters=0
x=str(location[m])
year="10"
years="2010"
var="u"
while counters<6:
    location=2368,2369,2370,2371,2766,2846
    directory="C:\\Users\\Brandon\\Documents\\ProjectI\\SecondThesis\\"+var+"\\ "+years+"\\Mississippi\\noblanks"
    output="C:\\Users\\Brandon\\Documents\\ProjectI\\SecondThesis\\"+var+"\\ "+years+"\\Mississippi\\noblanks"
    txt_files= os.path.join(directory, '*.txt')
    for txt_file in glob.glob(txt_files):
        with open(txt_file, "rb") as input_file:
            in_txt = csv.reader(input_file, delimiter="=")
            filename=os.path.splitext(os.path.basename(txt_file))[0]+''.csv'
            with open(os.path.join(output, filename), 'wb') as output_file:
                out_csv=csv.writer(output_file)
                out_csv.writerows(in_txt)
        m=m+1
    counters=counters+1
#This script is use to calculate mixing height from u and v components of wind
V=0#use to establish a variable
import os

```

## APPENDIX C

### PYTHON SCRIPTS: EXTRACT MIXING HEIGHT VALUES







```

y=glob.glob("*.csv")
z=y[b]
data1=open("C:\\Users\\Brandon\\Documents\\ProjectT\\SecondThesis\\v\\"+years+"\\Mississippi\\18z\\"+x+"\\")+z).read()
row=data1.replace("\n","")
row2=data1.replace("\n","")
if len(row)==1:
    uvalue=row[0]
    uvalue=float(uvalue)
    U=uvalue
elif len(row)==2:
    uvalue=row[0]+row[1]
    uvalue=float(uvalue)
    U=uvalue
elif len(row)==3:
    uvalue=row[0]+row[1]+row[2]
    uvalue=float(uvalue)
    U=uvalue
print U
if len(row2)==1:
    vvalue=row2[0]
    vvalue=float(vvalue)
    V=vvalue
elif len(row2)==2:
    vvalue=row2[0]+row2[1]
    vvalue=float(vvalue)
    V=vvalue
elif len(row2)==3:
    vvalue=row2[0]+row2[1]+row2[2]
    vvalue=float(vvalue)
    V=vvalue
print V
import math
a=math.pow(U,2)
j=math.pow(V,2)
k=a+j
M=math.pow(k,0.5)
U_2=U*srs
U_2=abs(U_2)

f=(2*7.2921*math.pow(10,-5)*math.sin(lats))
h1=abs(0.142*(U_2/f)) #equation to calculate mixing height
h1=int(h1)
d=yrs+"mh"+x+".txt"
os.chdir("C:\\Users\\Brandon\\Documents\\ProjectT\\SecondThesis\\mixingheight\\test")
newtxt=open(d,'a').close()
rh=open(d,"a") #open text file where the user has permission to append values to the text file
rh.write("\n") #create a new line for each new value
rh.write(str(h1)) #write the new value to the text file
rh.close() #close the text file
b=b+1
xy=xy+1
counters=counters+1

```